

# **Street Storage System for Control of Combined Sewer Surchage**

## **Retrofitting Stormwater Storage Into Combined Sewer Systems**

by

Stuart G. Walesh  
Valparaiso, IN 46385-2979

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Project Officer

Carolyn R. Esposito  
Water Supply and Water Resources Division  
National Risk Management Research Laboratory  
Edison, NJ 08837

National Risk Management Research Laboratory  
Office of Research and Development  
U.S. Environmental Protection Agency  
Cincinnati, OH 45268

## **Disclaimer**

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## Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air and waste resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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E. Timothy Oppelt, Director  
National Risk Management Research Laboratory

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## **Abstract**

A case study approach, based primarily on two largely implemented street storage systems, is used to explain the concept through construction and operation aspects of street storage systems. More specifically, the case studies address analysis and design approaches, the regulatory and funding framework, public involvement, construction costs, operation and maintenance procedures, and system performance.

Street storage refers to the technology of temporarily storing stormwater in urban areas on the surface (off-street and on-street) and, as needed, below the surface close to the source. Close to the source means where the water falls as precipitation and prior to its entry into the combined, sanitary, or storm sewer system. The idea is to accept the full volume of stormwater runoff into the sewer system but greatly reduce the peak rate of entry of stormwater into the system. System components include street berms, flow regulators, and surface and subsurface stormwater storage sites.

By eliminating or greatly reducing surcharging in combined sewer systems, street storage has the potential to cost effectively and simultaneously mitigate basement flooding and CSO's. Other possible benefits of street storage are mitigating SSO's, eliminating surface flooding, reducing peak flows at WWTP's, and controlling non-point source pollution.

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## **Abbreviations and Acronyms**

CCI	Construction Cost Index (provided by ENR)
cfs	Cubic feet per second
CMP	Corrugated metal pipe
CSO	Combined sewer overflow
CSS	Combined sewer system
CUP	Chicago Underflow Plan
CWA	Clean Water Act
DPW	Director of Public Works
EDA	U.S. Department of Commerce Economic Development Administration
ELSSD	Emerson-Lake Streets Sewer District
ENR	Engineering News-Record (Source of the CCI)
EPA	Environmental Protection Agency (same as USEPA)
gpd	Gallons per day
HSSD	Howard Street Sewer District
HUD	U.S. Department of Housing and Urban Development
IDOT	Illinois Department of Transportation
IEPA	Illinois Environmental Protection Agency
ILLUDAS	Illinois Urban Drainage Area Simulator
ITE	Institute of Transportation Engineers
mph	Miles per hour
MSDGC	Metropolitan Sanitary District of Greater Chicago (now the MWRDGC)
MSSD	Main Street Sewer District
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago (formerly MSDGC)
NMC	Nine minimum controls
POTW	Publicly-owned treatment works
RHS	Rural Housing Service
RUS	Rural Utilities Service
SAM	System Analysis Model
SASAM	Surface and Street Analysis Model
SRF	State Revolving Fund
SSS	Sanitary sewer system
SWMM	Storm Water Management Model
TARP	Tunnel and Reservoir Plan
USDA	U.S. Department of Agriculture

USEPA	U.S. Environmental Protection Agency (same as EPA)
WWF	Wet weather flow
WWTF	Wastewater treatment facility

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# **CHAPTER 1**

## **INTRODUCTION**

### **Combined Sewer System Challenge in the U.S.**

Much work remains to be done to solve the overflow and basement flooding problems caused by surcharging of combined sewer systems (CSS) in approximately 1000 U.S. communities. These communities, 60% of which are small in that they have populations of less than 10,000, have a total population of about 40 million or approximately 15% of the country's total. About 85% of the CSS municipalities are in eleven northeastern, midwestern and far western states. Within these communities are 10,000 combined sewer overflow (CSO) points and an unknown number of historic and potential basement flooding situations (Dwyer, T. 1998).

Most combined sewer municipalities face the challenge of how to mitigate overflows and/or basement flooding and the attendant water pollution, health risks, and monetary damages. The challenge is further defined by recognizing that the combined sewer problem must be solved to comply with state and federal regulations, recognize the realities of fiscal responsibility, and earn public acceptance.

Presented in this manual is a description and evaluation of what has proven, within a specific set of circumstances, to be one way of meeting the CSS challenge. More specifically, the technology described in this manual solved surcharging, complied with regulations, proved to be cost effective and earned public support.

### **CSO Policy of the USEPA**

#### ***Objectives of the Policy***

Three objectives guide the U.S. Environmental Protection Agency's (USEPA) CSO policy (USEPA 1994). They are:

- "...ensure that if CSOs occur, they are only as a result of wet weather."

- “...bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the Clean Water Act (CWA).”
- “...minimize water quality, aquatic biota, and human health impacts from CSOs.”

According to the USEPA (1994):

*Permittees with CSSs that have CSOs should immediately undertake a process to accurately characterize their sewer systems, to demonstrate implementation of the nine minimum controls, and to develop a long-term CSO control plan.*

### **Nine Minimum Controls**

Permittees with CSOs should, according to the EPA (1994), submit appropriate documentation demonstrating implementation of the nine minimum controls (NMCs), including any proposed schedules for completing minor construction activities. The nine minimum controls are:

2. proper operation and regular maintenance programs for the sewer system and the CSOs;
3. maximum use of the collection system for storage;
4. review and modification of pretreatment requirements to assure CSO impacts are minimized;
5. maximization of flow to the publicly-owned treatment works (POTW) for treatment;
6. prohibition of CSOs during dry weather;
7. control of solid and floatable materials in CSOs;
8. pollution prevention;
9. public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts; and
10. monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

John and Wheatley (1998) focus on the minimum and interim aspects of the NMCs when they state that the NMCs were:

*...not expected to require major capital expenditures and directed state environmental agencies to formulate their own strategies for bringing CSOs into compliance with water quality standards and other CWA requirements. The minimum controls can reduce CSO impacts on water quality but were not seen as a long-term solution.*

### ***Long-Term CSO Control Plan***

Permittees with CSOs are, according to the EPA (1994), responsible for developing and implementing long-term CSO control plans that will ultimately result in compliance with the requirements of the CWA. The long-term plans should consider the site-specific nature of CSOs and evaluate the cost effectiveness of a range of control options/strategies. The minimum elements of the long-term control plan are:

- Characterization, monitoring, and modeling of the combined sewer system.
- Public participation.
- Consideration of sensitive areas.
- Evaluation of alternatives.
- Cost/performance considerations.
- Operational plan.
- Maximizing treatment at the existing POTW treatment plants.
- Implementation schedule.
- Post-construction compliance monitoring program.

### **Traditional Approach: Store/Treat Combined Sewage or Separate the Sewer System**

Traditional and proven structural methods for resolving CSS flooding and pollution problems include, as shown in Table 1-1, separation, in-system storage, end-of-pipe storage, and deep tunnels. All the traditional solutions address the pollution problem while separation and in-system storage can also mitigate flooding problems, especially basement flooding caused by surcharging of combined sewers.

The premise of the traditional and proven solutions is to generally accept the rate of stormwater flow into the system. The resulting mixture of stormwater, sanitary sewage and other components is then controlled with methods such as in-system storage, end-of-pipe storage, and deep tunnels.

The Association of Metropolitan Sewage Agencies, in a study of 21 large U.S. communities having CSS's, reported that "storage is the most common approach taken to reduce the volume and frequency of overflows" (AMSA, 1994, p. 17). Storage in this context includes the in-system, end-of-pipe, and deep tunnels approaches listed in Table 1-1. Interestingly, nine of the 21 communities have constructed (Chicago, IL and Milwaukee, WI) or plan to construct tunnels. Two of the 21 studied communities, Minneapolis-St. Paul, MN and Hartford, CT have made major commitments to sewer separation.

**Table 1-1.** Proven methods are available to solve pollution and/or flooding problems in combined sewer systems.

Method	Problem Solved	
	Pollution	Flooding
Separation	✓	✓
In-System Storage <sup>1</sup>	✓	✓
End-of-pipe Storage <sup>1</sup>	✓	
Deep Tunnels	✓	

1) Storage of combined sewage.

## **A New Approach: Store Stormwater Before It Combines With Sanitary Sewage**

Wet weather problems in CSSs are caused by the peak rate of stormwater runoff, not necessarily by the runoff volume. Wet weather flooding and pollution problems would often not occur, or would be much less severe, if the peak flows of stormwater could be lessened. Peak flows are often the principal culprit, not the volume of stormwater runoff.

This suggests a fundamentally different approach having the following premise: reduce the peak flow rates of stormwater before it enters the combined sewer system. Accept the full volume of stormwater into the CSS, but greatly reduce the peak rate of entry. Figure 1-1 illustrates, in conceptual fashion, this stormwater-oriented approach to reducing surcharging in CSS and, therefore, mitigating flooding and pollution. Chapter 3 includes a detailed description of the conceptualization, development, design and construction of the street storage approach.

### **Scope of This Evaluation**

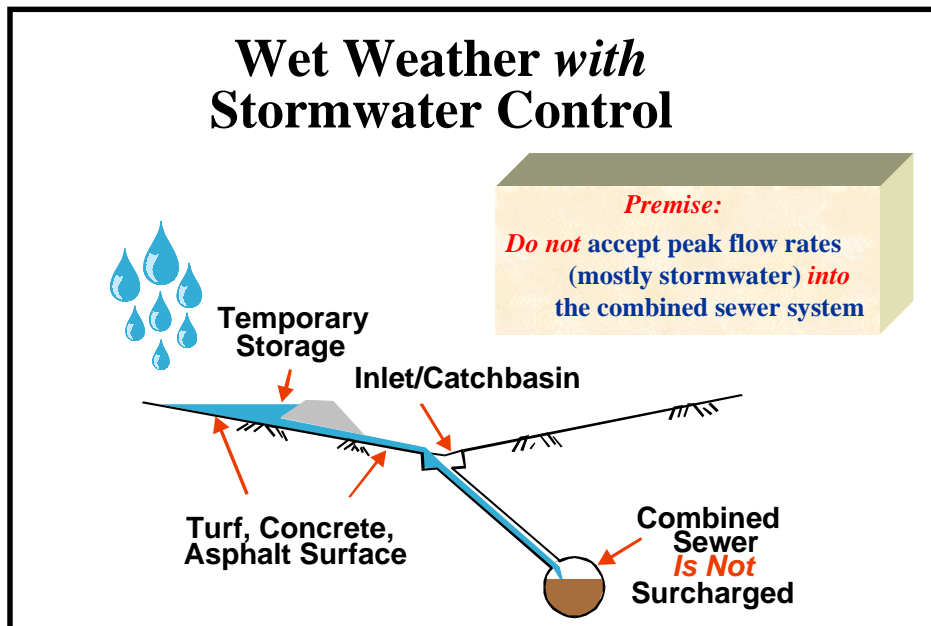
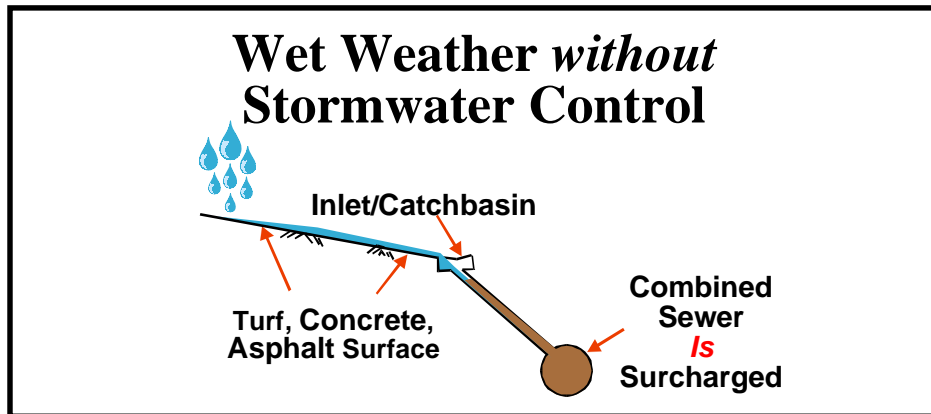
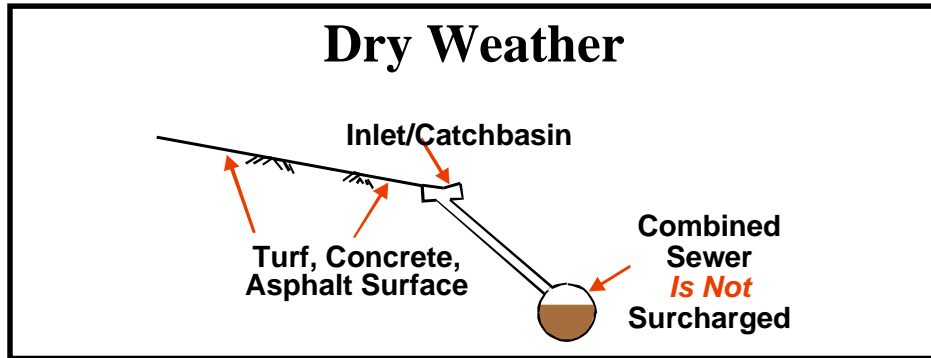
#### ***Case Study Approach***

This manual documents a case study-based evaluation of the use of on-street and related storage of stormwater to reduce the surcharging of combined sewers and, in turn, mitigate basement flooding and CSOs. The focus of the evaluation is capturing, analyzing, and presenting what has been learned through the concept-through-operation process over 18 years in primarily two communities. Synopses of several other applications are included as supplemental ways to learn about the street storage system approach.

The scope of this manual is broad. The evaluation includes many and varied aspects of the case studies such as analysis and design approaches, regulatory and funding framework, public involvement, operation and maintenance procedures and costs, construction costs, and performance of the system. The scope of this manual is also deep, that is, detailed. Each of the preceding topics are covered in depth. The scope of this manual is also broad in that it addresses both flooding and pollution caused by surcharging of CSS's. This quantity and quality issue is discussed in the next section.

### **Quantity and Quality: Seeking Optimum Means of Simultaneously Mitigating Flooding and Pollution**

Most CSS studies, reports and guidelines that are not community or site-specific, address only or mainly the need to reduce pollution caused by CSOs. Lost in this focus on pollution caused by surcharging of CSSs is the frequent parallel problem of basement and other flooding caused by surcharging of CSSs.



**Figure 1-1.** Control of peak rates of stormwater runoff can, in concept, mitigate surcharging of combined sewer systems.

As an indication of the possible local importance of basement and other flooding in CSS communities, consider the community-specific information provided in an assessment report prepared by the Association of Metropolitan Sewerage Agencies (AMSA, 1994). Described in this report are “CSO control programs” in 21 communities across the U.S. Although the focus of the report is clearly on CSS water quality, that is, pollution problems, water quantity problems, that is, flooding, are clearly evident in some of the 21 communities. The report states (AMSA, 1994, p. 15):

*In many of the cities, basement flooding during wet weather is also a problem that influences CSO improvements and **frequently impacts the selected control strategy (emphasis added).***

Flooding data on the previously mentioned 21 communities plus others is summarized in Table 1-2. Some type of flooding attributed to the CSS is explicitly reported by seven of the communities. Given the preceding quote, flooding problems may be under reported.

As an example of emphasis on pollution control in CSSs to the essential exclusion of flood control, consider the USEPA manual on combined sewer overflow control (USEPA, 1993). The stated purpose is to provide “...information to assist in selecting and designing control measures for reducing pollutant discharges from CSOs” (USEPA, 1993, p. 1). Although most of the report focuses on controlling combined sewage, there are scattered brief references to components of street storage. Examples are inlet restriction and attendant street ponding (p. 7), flow slipping (p. 7) and regulators (p. 38).

Several possible explanations can be offered for the strong focus on pollution caused by CSSs to the exclusion of addressing basement and other flooding problems.

First, pollution will almost always be a problem in CSSs while basement and other flooding problems are less likely to occur as evidenced by the AMSA (1994) assessment. Basements are essentially not present in some communities because of factors such as high groundwater levels and the presence of shallow bedrock. The actual severity and frequency of basement flooding, regardless of cause, is likely to be greater than reported because building owners may fear loss of property value if flooding of their basements is documented. However, when basements exist within a CSS, the resulting flooding by combined sewage can be a serious and repeated health risk and create large monetary losses.

**Table 1-2.** Seven of 22 large CSS communities explicitly reported basement or street and other surface flooding (AMSA, 1994 except where other source is indicated).

City	Type of Flooding Explicitly Reported As being Attributed to the CSS		
	Street and/or Other Surface Flooding	Basement Flooding	Undifferentiated Flooding
Atlanta, GA			
Boston, MA			
Chicago, IL		M	
Cincinnati, OH			
Cleveland, OH		M	
Columbus, GA			
Detroit, MI			
Fort Wayne, IN <sup>1</sup>		M	
Hartford, CT	M		
Louisville, KY	M	M	
Milwaukee, WI			
Minneapolis-St. Paul, MN			
New York, NY			
Philadelphia, PA			
Portland, OR			
Providence, RI			
Richmond, VA			
Sacramento, CA	M	M	
San Francisco, CA			
Seattle, WA			
Washington, DC			M
Wayne County, MI			

1) WERF, 1998, pp. 14-15

Second, the USEPA and counterpart state “environmental” agencies (e.g., Indiana Department of Environmental Management) tend to be concerned with pollution abatement. In contrast, flood control and drainage are within the mission of the COE and counterpart state agencies (e.g., Indiana Department of Natural Resources).

These flood control oriented agencies typically do not address problems in CSSs. Agency missions understandably drive agency programs. A possible negative aspect of exclusive or excessive focus on pollution abatement in CSSs is that less than optimum solutions may result. For example, a community’s CSO problem may be successfully resolved by end-of-pipe storage or end-of-pipe connection to “deep tunnels” while the basement flooding problem continues.

Optimum solutions are more likely to arise if the entire drainage system or watershed is examined from the outset in terms of defining the problem (pollution and flooding), determining the causes, and then finding the most cost-effective solution. The scope of this manual is holistic in that it stresses the possibility of simultaneously addressing quality and quantity, that is, pollution abatement and flood control.

### ***Retrospective Details With Prospective Purpose***

Because of the case study approach, the details of this manual are retrospective. That is, the emphasis is on history—what was done, why it was done, how it worked. However, in as much as municipal officials are the principal audience of this manual, the overall thrust is prospective. That is, how could other communities benefit from the concept-through-operation experience of the case study communities?

Each municipality has a unique meteorological, physical, socio-economic, political and regulatory profile. Therefore, only some of the knowledge gained from the case studies described in this manual will be transferable to any given community. However, given the breadth and depth of knowledge presented in this manual, if even a small part is directly applicable to a given municipality, that municipality will gain much. Stated differently, the specifics documented in this manual should prevent “reinventing the wheel” in other communities. The theme of relevance to other CSS municipalities is woven throughout this manual. Perhaps some communities will investigate the street storage option as a result of successes enjoyed by the case study municipalities.

In addition to having a prospective thrust to serve municipalities, this manual is also prospective for the benefit of researchers. Possible research topics are identified, (see Chapter 11), based on the case study experience, with the hope that additional investigations might be conducted.

## ***Initiatives***

As noted, this is a case study-based manual and, therefore, the details are largely retrospective. Accordingly, new research efforts were generally beyond the scope of the evaluation, with two specific exceptions.

The first exception to the retrospective focus of this manual is a literature search. Efforts were made to find, document and incorporate relevant papers, articles, and personal contacts not already discovered during the conduct of the two projects. Because the technology was considered innovative when first applied to the case study communities in the 1980's, a major effort was undertaken at that time to find relevant literature and knowledgeable individuals. Results of those efforts were included in early project documents and are summarized in this manual. The additional literature and resource search carried out for this evaluation was conducted to enhance the value of the manual. Findings of the literature search are included throughout this manual as supplements to the two case studies.

The second exception to the retrospective focus of this manual is the special analysis of the hypothetical impact of the control technology on the volume and frequency of CSOs and on peak flows at wastewater treatment plants. Basement flooding by combined sewage, not CSOs, was the major CSS concern in the two case study communities. However, the implemented solution may have the potential to mitigate CSOs and related problems. Therefore, that potential was studied in an exploratory fashion to further enhance the value of this manual. That study is described in Appendix F and the results are summarized in Chapter 9.

## ***Terminology***

Several terms have been used in recent years to describe controlling peak rates of stormwater flow as a means of reducing surcharging in CSS's. Utilization of different terms for essentially the same system can and probably has led to some confusion. Accordingly, various terms are discussed here for purposes of clarification and to show commonality among various research, development and engineering design efforts in the U.S. and elsewhere. A specific terminology and its definition is then set forth for use in this manual.

Terms in use include:

- **Runoff Control.** This terminology has been in use in the U.S. since at least the early 1980's. In fact, it was used in most of the written and spoken communication throughout the two principal case studies which are described in this manual. See for example, the numerous Donohue & Associates citations in the Cited References. However, this term, while suggesting stormwater, is too general. Many aspects of stormwater management could be called "runoff

control.”

- **Inlet Control.** This terminology appears in the title of writings by Hides (1994) and Pisano (1989) and is also used by Harza Engineering (1981). While inlet modification may be part of the overall stormwater control system, it is typically just one component. For example, other possible components are street berms and subsurface storage tanks. Therefore, the term inlet control is undesirable because it suggests an unrealistically simple approach.
- **Source Control.** This term, which was used by Kaufman and Lai (1978) and Walesh (1996), has appeal because the stormwater is to be temporarily stored as close as possible to the source, that is, to where it falls as precipitation. Unfortunately, this quantity-oriented use of “source control” conflicts with the predominantly quality-oriented use of “source control” in amendments to the Clean Water Act. In these amendments, “source control” is strongly associated with non-point source pollution.
- **Micromanagement of Stormwater.** This terminology, used by Carr and Walesh (1998), focuses on the local, detailed, intersection-by-intersection analysis and design process that is needed when attempting to reduce peak stormwater flows in existing urban areas. This analysis and the resulting design and construction of numerous, small structures may be characterized as “micro” when compared to the “macro” approach typically used in stormwater system analysis and design. “Macro,” in this context, refers to larger subbasins used in the analysis and the smaller number of larger structures, such as detention or retention facilities, typically designed and constructed. On the negative side, the term “micromanagement” is not, in and of itself, very descriptive. Additional description is needed to communicate the concept.
- **Street Storage.** This term has proved to be highly descriptive. It readily suggests the unconventional, but potentially effective use of streets to temporarily store stormwater. On the negative side, while on-street storage is typically an important aspect of reducing peak stormwater flow into a CSS, it is not the only form of storage. Other possibilities include off-street surface storage and storage below streets and parking lots. The short hand term “street storage” was selected for use in this manual. It appears in the title.  
Street storage means:

*a system that mitigates surcharging of CSSs, SSSs and stormwater systems by temporarily storing stormwater in a controlled fashion on the surface (mainly on-street but some off-street) and, as needed, below streets. Stormwater is stored close to the source, that is, where it falls as precipitation, and prior to its entry into the*

*sewer system. The full volume of stormwater runoff is accepted into the sewer system but peak rates are reduced, as a result of the storage, to flow that can be accommodated without surcharging.*

## **Abbreviations, Acronyms and Glossary**

Many abbreviations and acronyms are used, for the purposes of efficiency and communication, in this manual. In the interest of assisting the reader, the first use of an abbreviation or acronym in the manual is accompanied by its definition. After that introduction, the abbreviation or acronym is used in the remainder of the manual. For easy reference, a complete list of abbreviations and acronyms is included near the front of this manual.

Some readers may not be familiar with all the technical, regulatory and other terms used in this manual. Accordingly, a Glossary appears near the end of this document. Selected definitions were drawn from the “Glossary of Wet Weather Flow Terms” (USEPA, 1998) and from other sources, as indicated in the Glossary.

## **CHAPTER 2**

### **CASE STUDY COMMUNITIES: SKOKIE AND WILMETTE, IL**

#### **Bases of Selection of Case Study Communities**

Skokie and Wilmette, IL, the two principal case study communities, were chosen for this manual primarily for three reasons, as described here. Because this manual describes case studies of a newer technology, an opportunistic approach was taken to finding principal and supplemental case study communities whose experiences could be of value to other communities. The identified case study communities in effect provided “laboratories” in which the new street storage technology could be studied.

#### ***Familiarity of the Investigators With the Projects***

Each member of the four-member engineer team that conducted this investigation contributed significantly to the engineering, financing or other aspects of one or both of the two principal street storage system projects. By choosing the Skokie and Wilmette, IL as the two principal case study communities, optimum use was made of the first hand experience of the investigators.

#### ***On-Going Relationships With Personnel in the Case Study Communities***

Three of the four engineer members of the team that conducted this investigation have maintained on-going relationships with personnel in at least one of the two principal case study communities. This proved to facilitate ready access to data, information, and suggestions originating within the two communities.

#### ***Opportunity to Study a Large, Long-Standing Street Storage Project***

The Skokie, IL street storage system is the largest known application of this technology in the U.S. and possibly beyond. Furthermore, parts of the Skokie system have been in operation since 1983, providing many years of operating experience. By choosing Skokie for this case study, the manual captures the best known overall example of the street storage technology.

## **Supplemental Communities**

As a supplement to using Skokie and Wilmette as the principal case study communities, other smaller scale applications of street storage, or components of it, were sought. These applications is presented in Chapter 4.

The remainder of this chapter is devoted to detailed descriptions of Skokie and Wilmette, IL. Pertinent information on supplemental communities that have implemented street storage or some aspect of it is presented when those communities are discussed.

### **Description of Skokie, IL**

A detailed description of Skokie, IL is presented to provide context and data for understanding the case studies. Included in the description are physical attributes, meteorology, and history of CSS problems and proposed solutions to them.

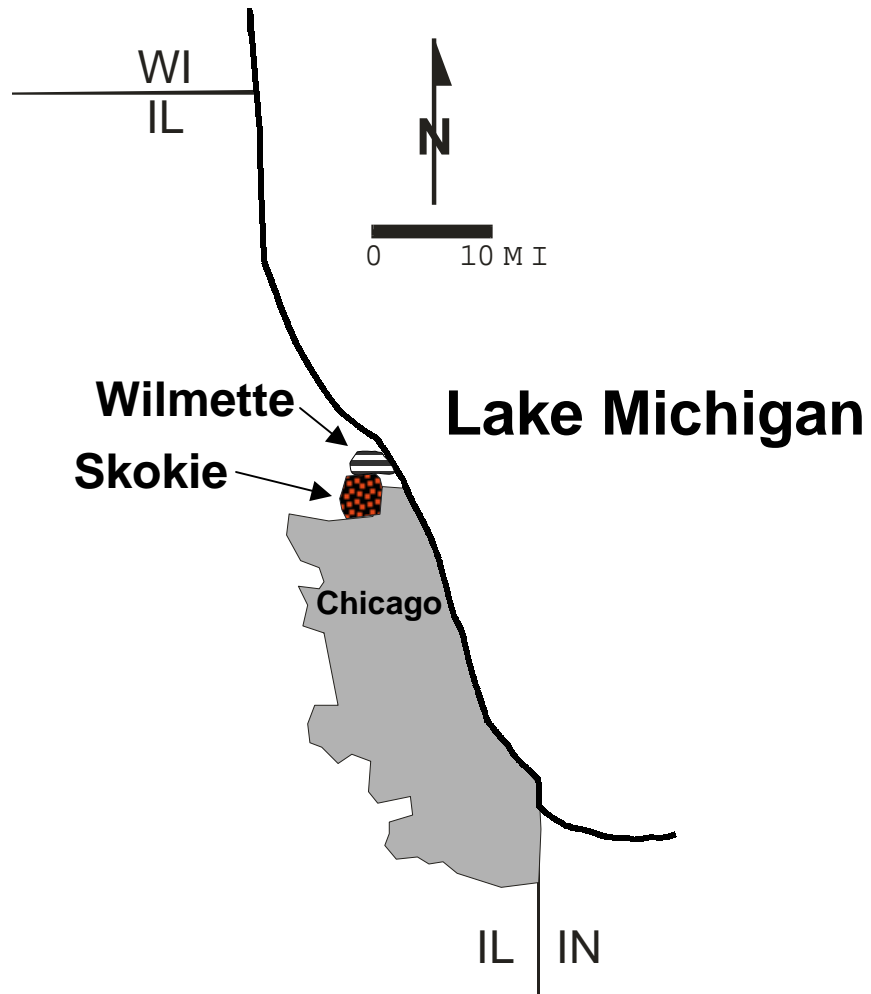
#### ***Location***

The general location of the 8.6 square mile Village of Skokie is shown on Figure 2-1. It is immediately north of the City of Chicago. Figure 2-2 is a map of Skokie showing major features. Skokie is bounded on the south by Lincolnwood, on the west by Niles and Morton Grove, on the north by Wilmette, and on the east by the North Shore Channel and Evanston. As suggested by Figure 2-3, which is a photo of the North Shore Channel, the channel and its associated linear parks are an amenity for area residents.

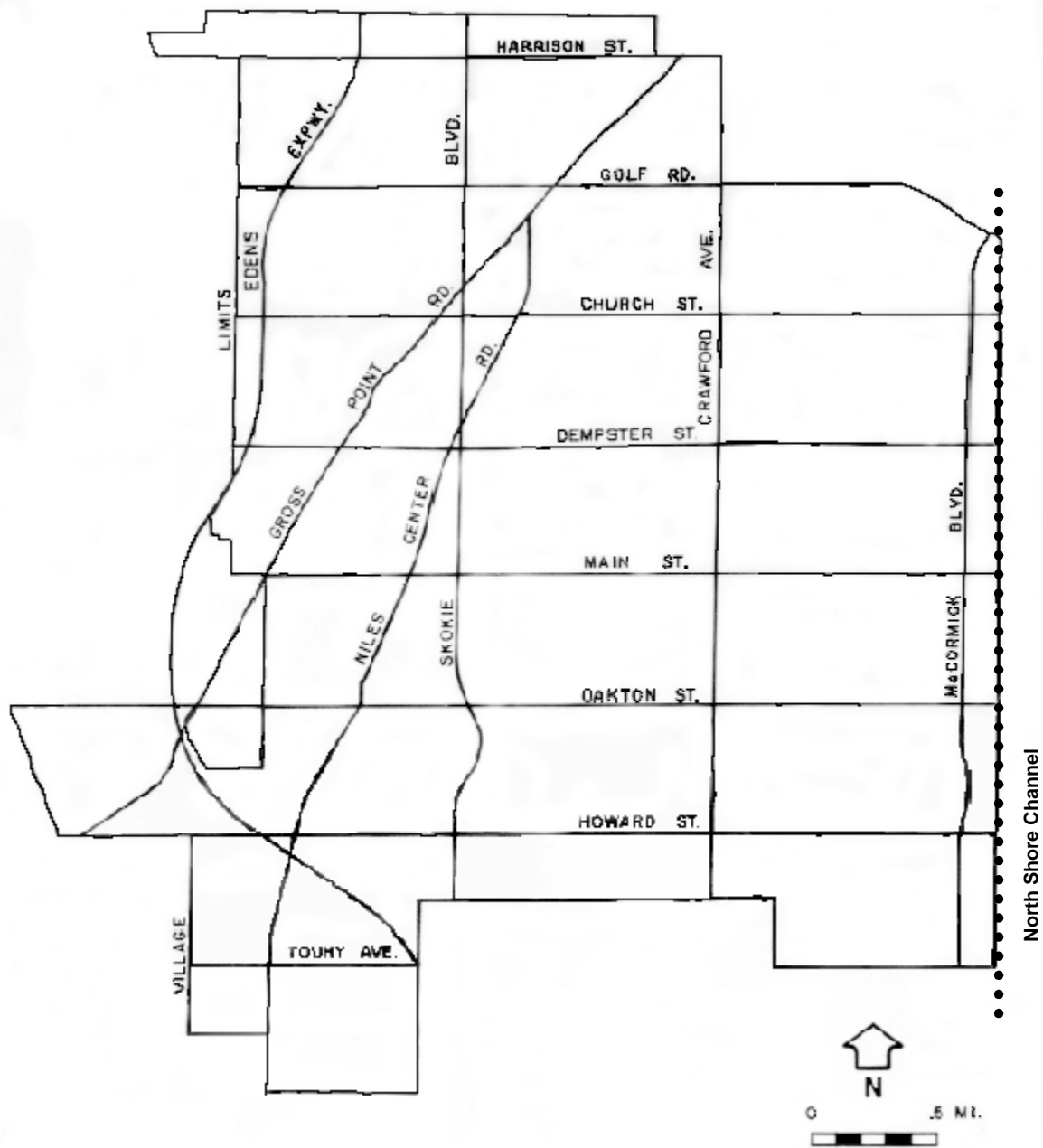
#### ***Relationship to the Metropolitan Water Reclamation District of Greater Chicago***

Skokie lies entirely in the service area of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). At the beginning of the Skokie street storage project, this agency was named the Metropolitan Sanitary District of Greater Chicago (MSDGC).

Essentially all of Skokie is served by a CSS. Combined stormwater runoff and sanitary sewage generated within Skokie flow generally eastward to interceptors and TARP (Tunnel and Reservoir Plan), also called the deep tunnel system, which is owned and maintained by the MWRDGC. As shown schematically on Figure 2-4, the interceptor parallels the North Shore Channel. The tunnel, which parallels and lies 200 feet below the North Shore Channel, is intended to capture, via drop shafts, combined sewage that is in excess of the interceptor capacity. As suggested by Figure 2-4, the deep tunnel is primarily a pollution control system. It mitigates CSOs but has minimal impact on basement flooding caused by surcharged combined sewers.



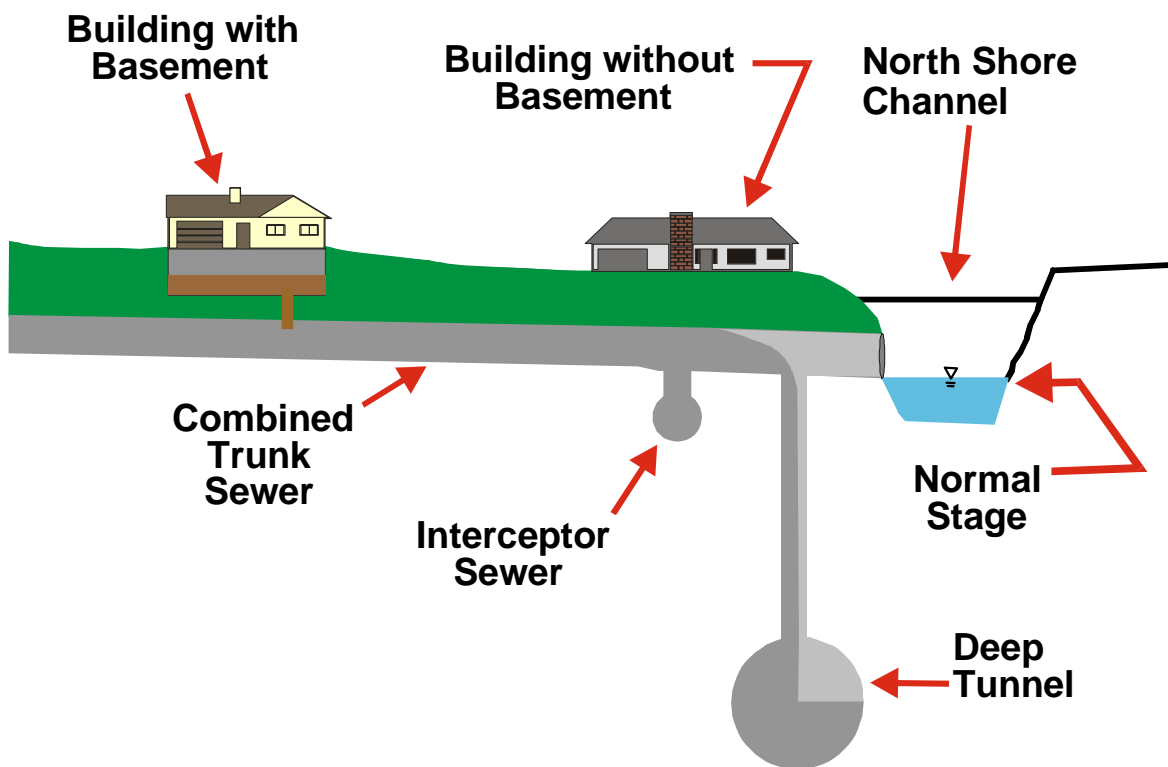
**Figure 2-1.** Skokie and Wilmette, IL lie immediately north of the City of Chicago.



**Figure 2-2.** Map of Skokie, IL (Source: Donohue, 1982b, p. 13).



**Figure 2-3.** The North Shore Channel, which bounds Skokie on the east, and its contiguous linear parks provide an amenity for area residents.



**Figure 2-4.** The deep tunnel is primarily a pollution control system in that it mitigates combined sewer overflows to the North Shore Channel.

Most drop shaft connections were provided to relieve the MWRDGC interceptors and not directly serve individual communities. However, proactive Chicago area communities such as Arlington Heights, Evanston, Niles, Skokie, and Wilmette were able to negotiate with the MWRDGC to provide drop shaft connections with agreed upon capacities to serve their CSSs. As a condition of placing these drop shafts, the communities were required to limit peak discharges to TARP. These conditions gave added impetus to Skokie and Wilmette, the two principal case study communities, to consider the street storage system.

### ***Land Use and Population***

Skokie is completely developed. Land use is about 80 percent residential, 10 percent industrial and 10 percent commercial. The population is about 60,000 persons with an overall population density of 11 people per acre and a population density in residential areas of approximately 14 people per acre (Nakai and Carr, 1993). There are about 20,000 single family residences in Skokie (Raasch, 1989b).

### ***Soils and Groundwater***

Skokie soils are primarily from glacial deposits of the Pleistocene series. These glacial deposits have an approximate depth of 60 feet and consist of many types of materials. About 25 percent of the community has sandy soils, while the remainder has clay soils. Groundwater levels are generally 10 to 15 feet below ground level in sandy areas. An exception is isolated perched lenses of shallower ground water (Nakai and Carr, 1993).

### ***Topography and Drainage Patterns***

“The land ...generally slopes eastward toward the North Shore Channel. Slopes vary from 0.1 to 1 percent and the overall slope in many areas of the Village is a flat 0.2 percent. Surface runoff ...flows from the front lawn and driveway areas to the street. Flow in the street is along the curb line and gutters to the nearest inlet. Inlets are generally located midblock and at intersections. Due to the extremely flat conditions, few areas have a continuous drainage pattern from block to block” (Nakai and Carr, 1993).

Trunk sewers in the combined system range in diameter from 30 inches to a maximum of 84 inches. Lateral sewers which are connected to trunk sewers vary in diameter from 12 to 27 inches. Combined sewage is carried from Skokie through three 84-inch trunk sewers to the MWRDGC interceptor sewer. When the interceptor capacity is exceeded each trunk sewer overflows first to the MWRDGC deep tunnel and then to the North Shore Channel (Nakai and Carr, 1993).

Stormwater leaves the street by flowing into an inlet, none of which have sumps, and

generally there are two inlets connected to a catch basin. As shown in Figure 2-5, catch basins are manhole-type structures containing some standing water in a sump at all times. The pipe conveying flow from the catch basin to the combined sewer is configured so as to form a trap preventing backup of sewer gases into the catch basin. Catch basins are generally located between the curb and sidewalk and have either a grated or solid manhole cover (Walesh and Schoeffmann, 1984).

Skokie is partitioned into three combined sewer districts. They are, as illustrated in Figure 2-6, the 1,255 acre Howard Street Sewer District (HSSD) in the southern part of the community; the 2,300 acre Main Street Sewer District (MSSD) in the central part, and the 1,955 acre Emerson Lake Streets Sewer District (ELSSD) in the northern part. As indicated earlier, the three districts drain generally easterly and flow into an interceptor sewer along the deep tunnel beneath the North Shore Channel (Nakai and Carr, 1993).

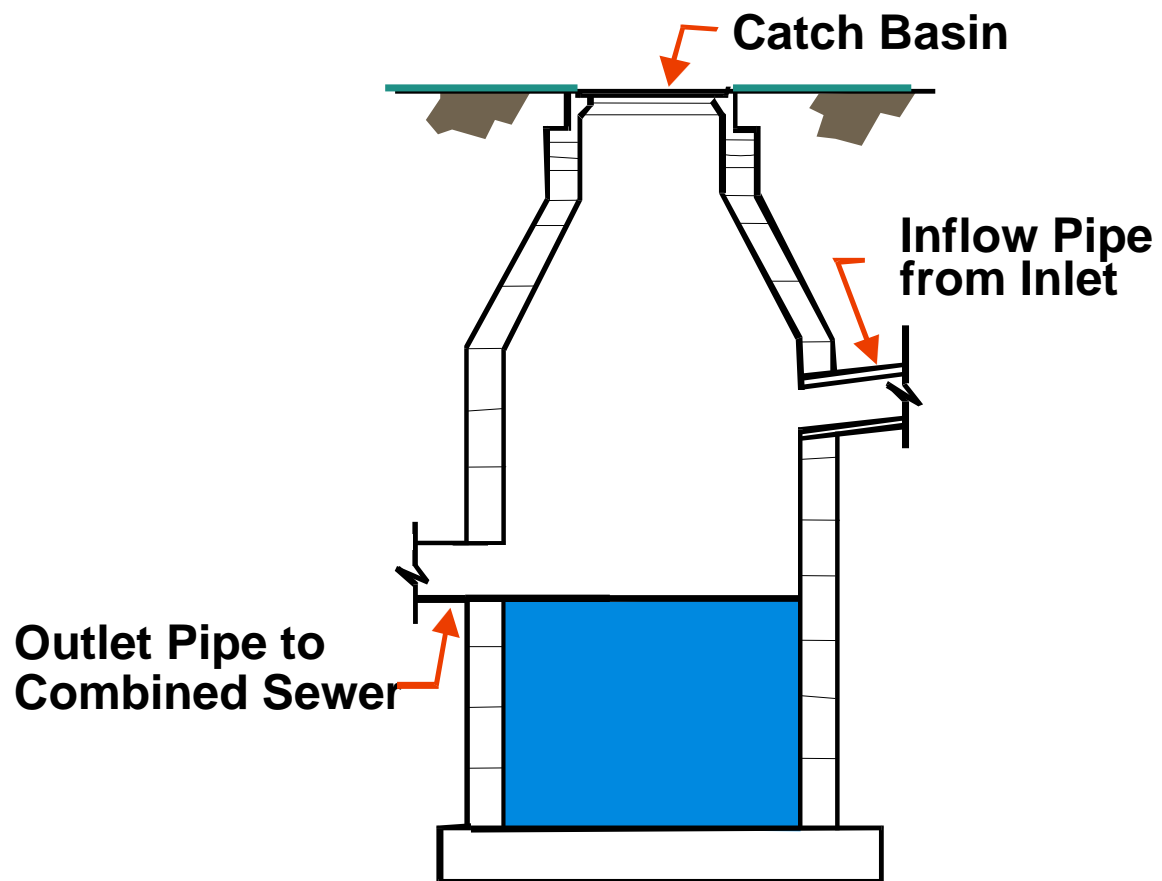
### ***Climate***

Skokie's climate is classified as continental, typical of a location in middle latitudes (42 degrees north latitude), but somewhat modified by the proximity of Lake Michigan which is two miles east of the community. Because of the lake, the climate is moderated relative to inland locations. Nevertheless, winters are cold, with an average snowfall of about 36 inches as snow, and summers are warm and sometimes humid. "All seasons are marked by occasionally intense storms that accompany changes from one air mass to another. Runoff from these storms, particularly in the spring and early summer, causes flooding in the Skokie area" (Donohue, 1982a, p. 29-31).

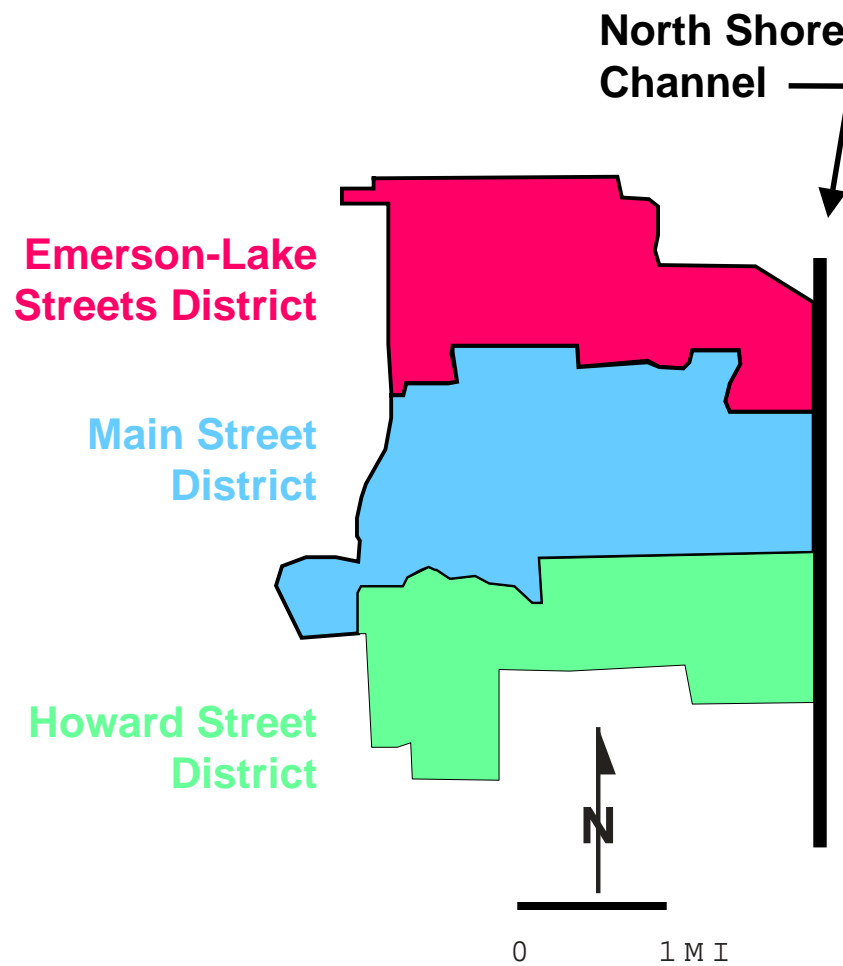
Nakai and Carr (1993) indicate that precipitation "...occurs as rain, sleet, hail, and snow and ranges from showers of trace quantities to brief intense storms to longer duration rainfall or snowfall events. Precipitation is distributed throughout the year with an average annual total of 33.3 inches." For a one-hour storm, the 1, 10, and 100-year recurrence interval rainfall amounts are 1.18, 2.10, and 3.56 inches, respectively. For a 24-hour storm, the 1, 10, and 100-year amounts are 2.51, 4.47 and 7.58 inches, respectively (Huff and Angel, 1989, pp. 29-30).

### **Brief History of Skokie with Emphasis on Development of Its Drainage System**

Sewer surcharging and basement flooding problems that gradually developed in Skokie can be traced back to the unique circumstances associated with development of the community. Most of what is now Skokie was under waters of Lake Michigan in prehistoric times. The community lies between two ridges approximately three miles apart and the area was mostly swamp when the first explorers arrived in the sixteen hundreds and found the Potawatomi Indians living there.



**Figure 2-5.** Each Skokie catch basin is a manhole-type structure with a sump.



**Figure 2-6.** Skokie is partitioned into three easterly draining combined sewer districts.

As the area became populated in the 1800's, the need for drainage and sanitary waste disposal became critical. Construction of the North Shore Channel in 1910, as part of the overall plan to provide the Chicago metropolitan area with an adequate drainage system, provided an outlet for sewers to serve Skokie. The first trunk sewer was constructed in 1886 to drain what is now the downtown area and carried both stormwater and sewage to the channel. Skokie's combined sewer system had begun.

The prime reason for the severity of the present basement flooding problem in Skokie is tied to the 1920's—the land boom days in Skokie. Major roads from Chicago were being paved and a rapid transit line extended through Skokie. As farm land was subdivided into building lots, population rose from 760 in 1920 to 4,200 in 1930. In preparation for the anticipated building boom, the majority of streets, sidewalks, water mains and sewers were constructed. The contemporary technology resulted in the construction of a combined sewer system with its outfall at the North Shore Channel. In 1927, a treatment plant and interceptor sewer system were constructed to handle dry weather sanitary flows, but the remaining mainly combined sewage flowed into the channel.

The depression of the 1930's brought the land boom in Skokie to an immediate halt. The constructed infrastructure was left essentially unused for the next 20 years. However, development anticipated in the 1920's finally occurred in the years following World War II. The majority of development and building took place in the 1950's as Skokie's population exploded from 14,800 in 1950 to 59,400 in 1960 (Walesh and Schoeffmann, 1984).

Not only did the community commit to an entire CSS but, trunk sewers were, unfortunately, undersized. More specifically (Consoer, Townsend & Associates, 1967):

*Because of limitations on financing, the original trunk sewer improvements were of an introductory nature and restricted in size. The lateral sewers were, however, installed to then standard practice. All of these sewers were combined storm and sanitary type.*

*It had been anticipated that additions to the combined sewers would be installed at intervals as buildings were constructed in the vacant areas. However, this program was not followed and as of today, all of the trunk sewers are deficient in capacity for an acceptable level of service. Basement flooding is prevalent during medium to heavy storms, and damaging street flooding also occurs*

*during the heavier storms.*

In summary, this brief history highlights the community's early commitment to combined sewers and the need, driven by finances, to undersize trunk sewers. This history also provides a segue to the next major section of this chapter which describes problems caused by Skokie's undersized CSS.

### **Skokie's Historic Combined Sewer System Basement Flooding Problems**

Several surveys over about a decade in the 1960's and 1970's documented widespread basement flooding in Skokie. According to Donohue (1982a):

*Previous studies by Consoer, Townsend & Associates, 1967 and 1973; the Village of Skokie, 1974; and by Harza Engineering Company, 1978, have included surveys to determine the extent of basement backup flooding in the Village of Skokie. These surveys were generally conducted by sending post cards to residences requesting information on their flooding history.*

*The 1967 survey received responses from over 9,000 residences with slightly in excess of 54 percent indicating that they had basement backup problems during major storms.*

*The 1978 survey resulted in about 2,500 responses, a response rate of only 11 percent. Approximately 15 percent of those responding, indicated they had basement flooding from recent rains which were less intense than a 2-year frequency storm. These backup problems were spread somewhat uniformly over most of the community. Interestingly, about 20 percent of the residences having flooding problems also indicated they had at least one flood protection device that obviously didn't work properly.*

*The 1974 survey by the Village was conducted only in the Fairview South area. During the survey, a questionnaire was mailed to each residence and Village personnel attempted to interview every homeowner. These efforts resulted in a 72 percent coverage of the 471*

*units and 47 percent indicated they had basement flooding during heavy rainfall. Again, a large percent of the people with some type of flood control equipment indicated they still had basement backup flooding problems.*

Viewed collectively, the three surveys (1967, 1974 and 1978) suggest a community-wide basement flooding problem caused by surcharging of the CSS. At least half of the residences appeared to experience basement flooding in larger storms. Furthermore, basement flooding occurred in a smaller but significant fraction of residences during frequent, minor storms.

### **Previous Studies of Ways to Solve Skokie's Combined Sewer System Basement Flooding Problems**

Skokie commissioned or conducted studies over a 15 year period to find a cost-effective solution to the growing basement flooding problem. Summarized here are the essential aspects of seven studies including the recommendations. This summary serves to illustrate how traditional solutions were repeatedly proposed but not implemented. This process, in turn, set the stage for Skokie's receptivity to a new approach.

#### ***Study Completed in 1967 Recommending Relief Sewers***

Consoer, Townsend & Associates (1967) conducted this community-wide investigation. Donohue (1982a, pp. 15-16) provides this summary:

*This study reviewed the sewer system deficiencies and backup problems in basements throughout the Village. It reviewed several alternative solutions to these sewer backup problems and recommended an overflow relief sewer system for the entire Village with an estimated 1967 cost of \$22.0 million (Note: The 1999 cost would be \$123 million using the Engineering News Record [ENR] Construction Cost Index [CCI]). In the Howard Street Sewer District the report recommended a major relief sewer along Laramie Avenue from Farwell Avenue to Brummel Street (48-inch to 102-inch diameter), then eastward along Brummel Street from Laramie Avenue to Hamlin Avenue (108-inch to 144-inch diameter), then two blocks south along Hamlin Avenue to Howard Street, and*

*east along Howard Street to the North Shore Channel (144-inch diameter). These sewers were never installed.*

*The proposed relief sewers were designed so that the combined capacity of the existing trunk sewers and the new relief sewers would be such that runoff from about a 15-year storm could be accepted from non-restricted areas and the actual maximum possible runoff could be accepted from restricted flat areas.*

### **Study Completed in 1973 Recommending Deep and Shallow Tunnels**

With the “deep tunnel” being imminent, Skokie retained Consoer, Townsend & Associates (1973) to carry out another community-wide investigation with emphasis on solving basement flooding problems. The following summary is provided by Donohue (1982a, pp. 16-17):

*In October 1972, the Board of Trustees of the Metropolitan Sanitary District of Greater Chicago (MSDGC) adopted the “Chicago Underflow Plan” (CUP). (This plan is later referred to as Tunnel and Reservoir Plan, TARP). The plan consisted of construction of 120 miles of conveyance tunnels intercepting the overflows from all existing combined sewers in the Chicago land area. One of the planned underflow tunnels paralleled the North Shore Channel and was scheduled for installation in the first phase of construction of the underflow plan. This provided a new outlet for the combined sewage flow from the Skokie sewer system and radically changed relief sewer concepts for the Village of Skokie. The 1973 Consoer, Townsend study analyzed the sewer facility needs for the Village of Skokie in conjunction with the CUP.*

*This report recommended a system of deep and shallow tunnels connecting to the MSDGC main tunnel along the North Shore Channel. The 1973 estimated cost was \$31 to \$35 million (Note: The 1999 cost range would be*

*\$98 to \$111 million using the ENR CCI). The system within the Village of Skokie included a major deep tunnel in an east-west direction down Main Street draining towards the North Shore Channel and several shallow tunnels in north-south directions draining to this deep tunnel. The Howard Street area would be served by shallow tunnels leading north along Laramie Street and Keeler Avenue. The report presented design data and cost estimates on systems sized for both the 10-year and 100-year storms. None of these deep or shallow tunnels have been constructed.*

*The study also analyzed the effect that the CUP would have on the existing trunk sewers if no relief sewers were provided. The report concludes that the North Shore Channel underflow tunnel will have a minor impact on Skokie flooding without supplementary channels or relief sewers being installed, except for several blocks near the outlet.*

### ***Study Completed in 1974 Recommending Downspout Disconnection and Catch Basin Restrictors***

Unlike all the other studies summarized in this section, this one was conducted by Skokie personnel. Donohue (1982b, pp. 17-18) contains this summary:

*This study was completed by the Village of Skokie to determine the probable relief that could result from downspout disconnection in the Fairview South area and catch basin restrictions. The restrictors were "half-moons" inserted into catch basin outlet pipes which effectively reduce their discharge capacity by one half. Twenty-seven percent of the downspouts in the area were found to be disconnected at the beginning of the study.*

*Detailed surveys were conducted by mailing questionnaires to residents of the Fairview South area and collecting these questionnaires by survey teams in the field. The survey*

*covered 72 percent of the residences and showed that of those surveyed, 47 percent have basement backup problems during heavy rainfalls. The survey also asked if residences had some type of flood control equipment installed. Of the 355 residences surveyed, 86 percent indicated that they had some type of flood control equipment installed. However, a large percentage of these residences still experienced sewer backup problems due to inadequacies or malfunctioning of their flood control equipment. Another question checked the citizen response to the acceptability of a future downspout disconnection program. Sixty-nine percent of the 355 residences surveyed voiced a willingness to participate in a downspout disconnection program.*

*Recommendations of the study were: 1) New catch basin restrictors should be installed at 86 locations to reduce the pipe diameter from eight inches to four inches thereby reducing the discharge capacity of the catch basins by 75 percent. The cost was estimated to be \$1,274. 2) A downspout disconnection program should be instituted and all residences in the study area except those fronting on Laramie and Pratt Avenues should be disconnected. Cost for this program was estimated at \$19,728. The net effect of this downspout disconnection program would be a 49 percent reduction in the demand placed on the sewer system. The study stated that the additional stormwater directed into the street by the disconnected downspouts and stored in the street by the restricted catch basins could be stored without causing major hazards to vehicular traffic in all areas of Fairview South except the west and south boundary streets, Laramie Avenue and Pratt Avenue, respectively. This study used the five and 10-year storms to analyze street flooding characteristics.*

As a result of this study, Skokie proceeded with a downspout disconnection program with the goal of disconnecting 95 percent of those in the HSSD in 1982. Also in keeping with the study's innovative recommendation, some restrictors were installed in catch basins. Unfortunately, most were removed because of plugging and maintenance problems (Donohue, 1982b, p. 18).

### ***Study Completed in 1978 Recommending Deep and Shallow Tunnels and Relief Sewers***

The entire Skokie CSS was the target of another study, this one conducted by Harza Engineering Company (1978). As with the 1973 study, this investigation was carried out with the understanding that TARP would eventually be a reality and, therefore, provide an improved outlet for Skokie's CSS. The following summary is provided by Donohue (1982b, pp. 18-19):

*This study analyzed the combined sewer system in the Village of Skokie and reviewed alternative ways to improve the system performance and mitigate existing problems. The study related that the lateral sewers, characteristically about two blocks long with a maximum diameter of 18 inches, would have sufficient capacity such that backups in basements would occur only about once in 25 years if the downstream branch sewers were adequate to handle the lateral sewer discharges. These existing branch sewers, however, have about one-half of the capacity needed to convey the flow which the lateral sewers can deliver. The large trunk sewers into which the branch sewers flow have less than one-half of the capacity required to convey the flow from the branch and lateral sewers. Thus, the overall sewer system capacity decreases drastically in a downstream direction causing a flow constraint and resulting in under utilization of the upstream features of the sewer system.*

*Mitigation concepts that were investigated included homeowner protection devices, reduced rate of stormwater runoff into the sewer system, separate storm sewer systems, and increased capacity of the existing sewers.*

*The report recommended that the Village proceed with a program to increase the capacity of the existing sewers. This increased capacity would be accomplished by construction of a system of deep and shallow tunnels connecting to the MSDGC main stream tunnel system. Installation of some parallel branch sewers to convey additional flow to the tunnel system was also recommended. This system was sized to provide conveyance capacity for runoff from a 10-year frequency storm with Phase I of TARP in place and functioning. The 1978 cost estimate for these improvements was \$78 million (Note: The 1999 cost would be \$168 million using the ENR CCI). None of the improvements have been constructed.*

### ***Study Completed in 1981 Providing Additional Insight Into System Inadequacies***

The MSDGC (now the MWRDGC) studied the performance of the ESSD after two summer of 1981 storms caused basement and street flooding (Paintal, 1981). This investigation, as summarized in the following Donohue description (1982b, pp. 19-21), characterizes the capacity problems in and other aspects of the CSS:

*The MSDGC completed a study analyzing the performance of the Emerson Street Sewer District during two heavy storms that occurred over the Skokie area in the months of July and August 1981. These storms produced runoff rates which exceeded the capacity of the local sewer system resulting in street and basement flooding. The purpose of this study was to analyze those storms relative to the capacity of the Emerson Street sewer system. This system is a 1,740 acre area in the northern part of the Village of Skokie and is fairly similar in structure to the Howard Street system. The study analyzed the following:*

- The frequency of the July 12 and August 14, 1981 storms.*
- The sensitivity to flooding of the local*

*sewer system relative to the water level elevation in the North Shore Channel.*

- *The effects of downspout disconnection and house flood control-pumping systems on lateral sewer flows.*

*Although this analysis was performed on the Emerson Street District, most of the results and conclusions are pertinent to the Howard Street Sewer District and are summarized as follows:*

- *Submergence of the sewer outlet at the North Shore Channel does not affect the sewer capacity significantly if the water level in the channel does not rise above elevation 5+/- Chicago City Datum.*
- *The storms of July 12 and August 14 had a frequency of recurrence of once in 40 years and once in five years, respectively. The Emerson Street sewer, had it been designed for a five-year storm, would have adequate capacity to handle the flows generated by the above storms. The Lawler Avenue sewer (a local lateral similar to the laterals in the Howard Street District), had it been designed for a two-year storm, would have conveyed the flows generated by these storms.*
- *In order to negotiate the storms, the Emerson Street sewer should have a capacity of 1 to 1.2 cubic feet per second (cfs) per acre in comparison to the actual capacity of 0.13 to 0.2 cfs per acre. The capacity of the sewer is about one-fifth of what was required.*
- *Had the sewer been of adequate capacity, the flow at the outlet would*

*have been 1,600 cfs from its service area of 1,740 acres. That is equal to 0.92 cfs per acre. It is noted that TARP (Phase I) is designed for 1.0 cfs per acre drainage intensity.*

- *The results of an analysis of the Lawler Avenue (south) sewer to study the effect of downspout disconnection and individual house flood control pumping systems on the performance of the sewer system indicated that:*
  - *For short duration storms the disconnection of downspouts from the sewer system reduces the flow in the sewer significantly if the flow from the downspouts is directed to lawns and other porous areas.*
  - *The flood control pumping system protects the house but overloads the sewer system due to pumping during periods of peak flow and wet weather. If every house in the area has this kind of system, the pumpage alone will account for about 50 percent of sewer capacity depending on the size of the lateral sewer.*

*Additional analyses were completed in an addendum to this report. The addendum reviewed the effect that TARP - Phase I would have in reducing sewer surcharging particularly in the lower reaches of the Emerson Street District. This analysis concluded, had TARP - Phase I been in place during the July 12, 1981 storm, sewer surcharging and basement flooding would have been eliminated or considerably reduced within about 10 percent*

*or 170 acres of the Emerson Street sewer service area which is near the sewer outfall at the North Shore Channel. A similar reduction in surcharging would be felt in the Howard Street Sewer District with TARP - Phase I completed. The actual reduction in number of basements flooded will be somewhat less in the Howard Street district since development nearest the North Shore Channel is predominately industrial and commercial with no basements.*

### ***Study Completed in 1981 Suggesting Combinations of Traditional and Innovative Measures***

Harza Engineering Company, which had completed a system wide study in 1978, was called on again to explore options (Harza, 1981). Now the principal stimulus for another study was greatly reduced probability of USEPA funding. The following summary is provided by Donohue (1982b, pp. 21-22):

*Harza Engineering Company completed a supplemental study of flood control alternatives in 1981. This was a follow-up to their 1978 report which recommended implementation of a system of relief sewers that would connect to the Metropolitan Sanitary District of Greater Chicago's main tunnel under the North Shore Channel. Implementation of the relief sewers was predicated on a significant amount of funding coming from the USEPA. Since funding from the USEPA was no longer probable, this supplemental study was undertaken to identify solutions that could be implemented without federal aid.*

*Alternatives discussed in the study were grouped into conveyance, flood protection, inlet control, and combinations of these concepts. The conveyance concepts included relief tunnels and sewers (estimated cost of \$160 million for 10-year capacity), separate sewers (estimated cost of \$120 million), and sewer lining (not adequate alone). Flood protection consisted of individual flood protection devices such as overhead sewers (estimated cost of \$75 million). The review of inlet control looked at some typical depths of street flooding that would be anticipated if inlet controls were installed at the inlets without significant subsurface or other off-street storage. The cost of inlet controls alone, without storage, was estimated at \$2 million. Combinations of the above were packaged to provide alternatives with the best features of each single approach to maximize benefits for targeted expenditure levels. Various combinations of inlet controls with storage and conveyance improvements were estimated to range as high as \$60 million (Note: The 1999 cost of the separate storm sewers would be \$203 million using the ENR CCI. This is consistent with earlier IEPA (Park, 1990) estimates).*

### ***Study Completed in 1982 Recommending a Street Storage System***

Skokie retained Donohue and Associates in January 1982 to undertake a preliminary engineering study of what was then called runoff control but, for purposes of this case study manual and as explained in Chapter 1, is referred to as a street storage system. The HSSD was selected for this preliminary engineering project as an initial study area. Included in the scope of services for this project, which was completed in July 1982, were data inventory, hydrologic-hydraulic modeling, development of alternatives with cost estimates, and implementation recommendations (Donohue, 1982a, 1982b).

As the preliminary engineering project proceeded, nine alternatives were created for the HSSD. They ranged from flow regulators only to various combinations of flow regulators, underground storage and relief sewers. All alternatives "...were intended to minimize sewer backup into basements and maximize utilization of available street flooding capacity" (Donohue, 1982b, p. 3). This was the first time that utilization of street storage was the sole basis for solving Skokie's basement flooding problem. The series of previously discussed studies had evolved to the point where the innovative,

lower cost, street storage concept was explored in detail. The idea was to focus on the cause of CSS surcharging, that is, stormwater runoff, and explore ways to intentionally store stormwater on streets in a controlled fashion. Traditional approaches were, at least for the duration of this preliminary engineering study, held in abeyance. The recommended street storage system consisted of approximately 1200 flow regulators, 24 supplemental storage facilities, and a relief sewer. (The constructed project required only 10 supplemental storage facilities). The storage and sewer facilities were sized, in this preliminary engineering study, for a 10-year recurrence interval storm. Flow regulators would range in location and function from modification of existing inlet grates to orifice type or energy dissipating type flow regulators installed in the sewer lines leading from catch basins or inlets to the sewer system.

Storage facilities were recommended for all areas where street ponding would exceed the depth at which damage to adjacent private property could occur. This below street or off-site storage will reduce street ponding depths to just below damaging levels.

The estimated mid-1982 construction cost for the recommended HSSD street storage system was \$11,220,000. This cost was much less than the cost of traditional approaches and, as a result, was attractive to community decision makers. Opportunities to improve the cost-effectiveness of the design and reduce the total construction cost would be available as more detailed designs were prepared. Additional maintenance costs associated with the recommended street storage system were projected to be minimal.

A pilot program was recommended during the design and initial construction phase of implementation. The pilot program would evaluate various types of flow regulating devices and assess their operational aspects and maintenance requirements.

A monitoring program was recommended to evaluate the existing uncontrolled system and the performance of the pilot street storage system. The following five types of data collection and analyses were recommended: rainfall, sewer flow, street ponding, depth in storage facilities, and foundation drainage flow.

Unlike the recommendations in previous studies, the preceding recommendations were implemented. The commitment to finally take action was probably due to a combination of growing severity of the basement flooding problem and the promised low cost of the street storage system. The gradual, successful implementation of the recommendations in the preliminary engineering study, led to more recommendations which were in turn implemented. As of 1999, the street storage system has been almost completely implemented throughout the 8.6 square mile community. And, as explained in Chapter 9, the system performs very well. The details of the planning, design, testing, construction, financing and operation of the Skokie street storage system are presented in the remainder of this manual.

### **Observations Regarding the Studies to Solve Skokie's Combined Sewer System Basement Flooding Problem**

The Skokie experience in conducting a series of studies to solve its basement flooding problem contain ideas that can be advantageously transferred to other communities. Consider the three observations discussed here.

### ***Occurrence of a Series of Evolving Studies***

In an attempt to solve its growing basement flooding problem, Skokie commissioned or conducted a series of seven evolutionary studies over a period of 15 years. This pattern of serial, evolutionary studies is common in the public works environment.

The evolutionary nature of the Skokie studies is readily illustrated. For example, the 1967 study recommended relief sewers whereas the 1973 study, informed by the MSDGC's adoption of TARP, recommended tunnels that could connect to the TARP system. Recognizing that USEPA funding was probably no longer available, the 1981 study explored more innovative, low cost options, including street storage.

The study-no action, study-no action, etc. pattern is especially characteristic of wet weather problems. This is caused by the random, episodic nature of such problems. One or more damaging episodes occur, adversely affected citizens express concern, and community officials take action by initiating a study. By the time the study is completed and recommendations made, the intensity of interest in solving the problem has diminished, especially in light of implementation costs. In contrast with the random, episodic nature of CSS, SSS, stormwater system and other wet weather problems, most public service problems persist or at least are much less episodic, until solved. Examples are deteriorating streets, poorly performing schools, deteriorating quality of water supply, and inadequate police protection.

### ***Initial Focus on Traditional Solutions***

Most of the earlier studies considered and recommended traditional solutions to Skokie's basement flooding problem. Examples are relief sewers and tunnels. Widespread consideration of—but not necessarily recommendation of—innovative options was stimulated by lack of external funding. Reductions in or limitations of financial resources encourages creativity.

### ***Gradual Recognition of the Water Pollution Control Purpose of TARP***

The series of studies and the improved understanding of TARP gradually led to the realization that while the massive, expensive TARP would mitigate CSOs it would have minimal impact on the basement flooding problem. For example, the MSDGC's 1981 study concluded that basement flooding would have been eliminated in less than 10 percent of Skokie buildings had TARP been in place during the two summer 1981 storms. Unless something was done, post-TARP Skokie would still have a massive basement flooding problem because of its CSS.

## **Description of Wilmette, IL**

A description of Wilmette, IL is presented as a basis for understanding the case studies. Less detail is provided for Wilmette than for the previously described Skokie, for three reasons. First, some of what applies to Skokie also applies to Wilmette given that the latter is contiguous with and north of the latter. Second, more background information is needed for the much larger and longer duration Skokie project because it is emphasized in this case study manual. Third, less background documentation is available for Wilmette.

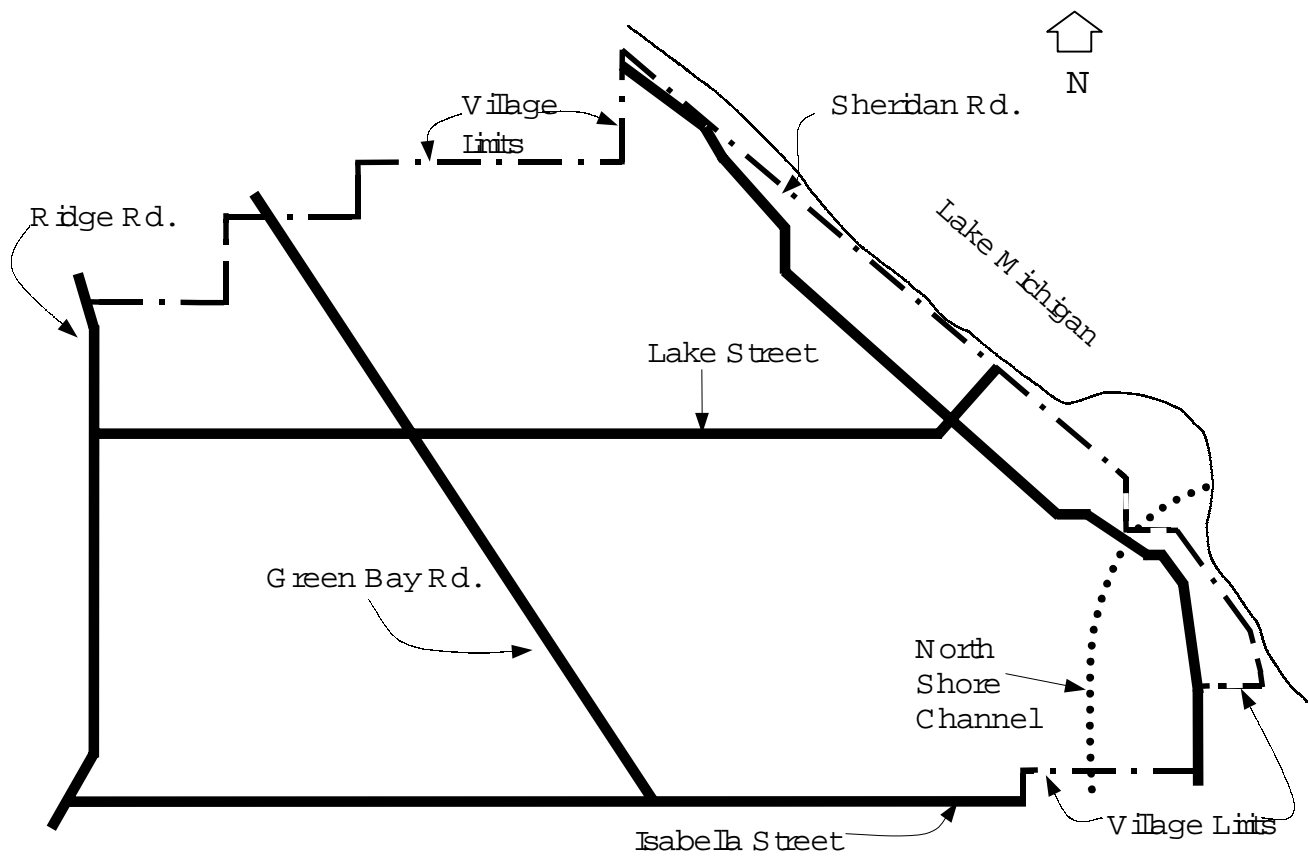
### ***Location***

As indicated on Figure 2-1, the Village of Wilmette is contiguous with and immediately north of Skokie. Figure 2-7 is a map of Wilmette showing major features. Besides being bounded on the south by Skokie and Evanston, Wilmette is bounded on the west by Glenview, on the north by Kenilworth and Northfield and on the east by Lake Michigan. The North Shore Channel, which as previously noted forms the east boundary of Skokie, passes through an eastern extremity of Wilmette before discharging into Lake Michigan. As also is the case in Skokie, the North Shore Channel, or more specifically, land paralleling it is an amenity for Wilmette. These lands include a public golf course and Gillson Park.

### ***Relationship to the Metropolitan Water Reclamation District of Greater Chicago***

Combined sewers serve the 2.0 square mile portion of Wilmette lying east of Ridge Road. Note that this CSS area is slightly less than one fourth of the CSS area in Skokie. The rest of Wilmette, which lies west of Ridge Road, is served by a separate sewer system (Loucks and Morgan, 1995). The Wilmette description presented in the remainder of this section applies primarily to the CSS area.

Wilmette's CSS lies in the service area of the MWRDGC. Combined sewers generally flow eastward. Connections to MWRDGC interceptors occur in the central portion of the CSS along Green Bay Road and on the east end of the CSS along Sheridan Road and the North Shore Channel. The Wilmette CSS is connected to TARP via two drop shafts along the North Shore Channel (SEC Donohue, December 1992, pp. 4-5). The initial CSS did not contain many trunk sewers because of the large number, relative to Skokie, of connections to MWRDGC interceptors.



**Figure 2-7.** Map of a portion of Wilmette, IL served by combined sewer system.

### ***Land Use and Population***

Approximately 80 percent of the fully developed Wilmette CSS is occupied by single family residences. The remainder is commercial and multiple family dwelling units. The 2.0 square mile CSS has a population of 11,300 and contains approximately 3500 buildings. The overall population density is 9 people per acre and the population density in residential areas is about 11 people per acre. To reiterate, the area is completely developed (SEC Donohue, December 1992, p. 4).

Note that the Wilmette and Skokie CSSs are similar when compared on the basis of type and intensity of land use. Each is fully developed, about 80 percent single family residential, and has an overall density of about 10 people per acre (Skokie: 11, Wilmette: 9).

### ***Topography and Drainage Patterns***

As noted earlier, the general drainage direction within the Wilmette CSS is eastward. Longitudinal street slopes are very flat. For example, 364 street segments within the CSS having a total length of 36.2 miles were examined. A street segment would typically be one block in length. Because of traffic volume, safety considerations or steep longitudinal slopes, 24% of the streets were determined to be not suitable for street storage. However, of the remaining 76% of street segments, 66% had longitudinal slopes of less than 0.25% (0.25 feet per 100 feet), 21% had longitudinal slopes of 0.25% to 0.50%, and only 13% had longitudinal slopes in excess of 0.50% (SEC Donohue, June, 1992, pp. 12-16).

One way in which Wilmette differs from Skokie is the presence of some brick streets. Of the 26.2 lineal miles of streets available for street storage, 50% are constructed of brick, 48% of asphalt, and 2% of concrete (SEC Donohue, June, 1992, p. 15). Figure 2-8 shows one of Wilmette's brick streets. They are highly valued because of their appearance. The brick streets were fully incorporated into the street storage system without compromising their aesthetic values. For example, a mid-block berm is shown on Figure 2-8.

The CSS contains about 33 miles of sewers that vary from eight to 72 inches in diameter. Smaller sewers—less than 30 inches in diameter—are generally formed of clay tile while the sewers larger than 48 inches in diameter are made of reinforced concrete. Combined sewers in the 30 to 48 inch diameter range could be clay or concrete. No combined sewers are constructed of brick (SEC Donohue, December, 1992, p. 4).



**Figure 2-8.** Brick streets account for half of the street length in Wilmette targeted for street storage.

## **Brief History of Wilmette with Emphasis on Development of Its Drainage System**

Partly as a result of the Chicago fire of 1871, the population of what is now Wilmette increased to over 300 which was the number required for incorporation. Wilmette was incorporated in 1872 and its first water and sewer systems were built in 1893-94. The combined sewer system, which was the accepted type of sewer system at that time, discharged into Lake Michigan.

As noted earlier, Wilmette, contrasted with Skokie, originally did not contain many trunk sewers because of numerous connections to MWRDGC interceptors. The entire system was generally under capacity. Relief sewers were constructed prior to 1960, but they were also undersized.

This discharge location and the shape of the Wilmette lakefront changed in the 1908 to 1910 period with construction of the North Shore Channel and the interceptor system. Spoil from the channel construction was used to create a landfill, north of the North Shore Channel, which is now Gillson Park. Therefore, Wilmette, like Skokie and many other Chicago area communities, made a major historic commitment to combined sewers and they proved to be undersized.

### **Wilmette's Historic Combined Sewer System Basement Flooding and Peak Discharge Problem**

Like Skokie, Wilmette had a long-standing, widespread basement flooding in its CSS. SEC Donohue (December, 1992, p. 2) provides this description:

*The combined sewer area of the Village of Wilmette... experiences basement flooding during moderate and heavy rainfalls. A postcard survey conducted following a heavy rain in August 1989 reported that nearly 800 buildings (23%) in the combined sewer area were flooded during this storm. More recent community surveys indicate that a substantially greater number of homes are actually impacted. These surveys indicate that over 60% of the buildings in the combined sewer area have been affected by basement flooding at one time or another.*

A subsequent report by Rust (November, 1993, p. 1) reports the preceding and notes that, besides property damage, flooding of basements with combined sewage exposes residents to health problems. According to this report, basement and street flooding problems "...occur regularly every one to two years during intense rain storms." The

report also notes that, as a result of uncontrolled street flooding, emergency vehicles have been delayed during storms.

As Wilmette sought a solution to its basement and street flooding problem in the early 1990's, it also had to resolve a related problem. As explained by Loucks and Morgan (1995), Wilmette needed to reduce the peak discharge from its sewer system:

*...to facilities of the MWRDGC. The MWRDGC is responsible for transportation, treatment and eventual discharge of sewage flows in Wilmette and 185 other communities. Approval from MWRDGC is required for all system modifications and new discharge connections. Projects consisting only of relief sewers are generally unacceptable. Hydraulic simulations were used to demonstrate a reduction of 28 percent in the peak discharge from the village. A maximum total peak release rate was negotiated with MWRDGC which serves as a constraint on the system design.*

Reduction in peak flow from the CSS, which was not an issue in the planning and early design of the Skokie street storage system, was a factor in the planning and design of the Wilmette system. The added value achieved in Wilmette is significant. It points to the potential for a street storage system to serve other functions such as reducing peak flows in interceptor sewers and at WWTFs.

### **Previous Studies of Ways to Solve Wilmette's Combined Sewer System Problems**

Several studies were carried out in the early 1990's. Key studies are briefly described here as an explanation of how and why Wilmette decided to implement a street storage system in its 2.0 square mile CSS.

#### ***Study Completed in 1991 Recommending Relief Sewers***

According to SEC Donohue (June, 1992, p. 5), RJN Environmental Associates, Inc. completed a facility plan for Wilmette in 1991. Focusing on solving the basement flooding problem, the plan "...recommended construction of combined relief sewers to increase the existing combined sewer system capacity to transport a 10-year storm event without surcharging." The estimated 1991 construction cost was \$65,000,000. The 1999 cost would be \$81 million using the ENR CCI.

#### ***Value Engineering Study Completed in 1992 Recommending Street Storage***

Donohue & Associates, Inc. and Lewis & Zimmerman Associates, Inc. were retained by Wilmette to participate in a value engineering study of the previous study (SEC Donohue, June 1992, p. 5; SEC Donohue, December 1992, p. 2). Completed in January 1992, the value engineering study concluded that what is defined as street storage in this report "...appeared to offer a higher level of protection against basement flooding at a cost of \$46,000,000 or substantially less than the \$65,000,000 recommended in the RJN facility plan."

### ***Study Completed in 1992 Recommending Street Storage***

Wilmette retained Donohue & Associates in March of 1992 to "...determine the technical and economic feasibility of using runoff control techniques such as temporary street ponding to relieve basement flooding problems in the east side areas" (SEC Donohue, June 1992, p. 5). The scope of services for this project was similar to that of the preliminary engineering study completed by Donohue for Skokie in 1982.

Completed in June 1992, the study concluded that "...a stormwater runoff control program consisting of temporary street ponding along with relief sewers will provide a cost-effective level of protection against basement flooding in the combined sewer area east of Ridge Road" (SEC Donohue, June 1992, p. 1). The report went on to point out significant potential cost savings over the previously recommended conventional relief sewer system. More specifically, the report stated:

*The estimated cost for a system of temporary street ponding berms and relief sewers which provide full protection against basement flooding and dedicated runoff storage capacity for a 10-year event is \$28,000,000. ...The estimated cost of the 10-year ...capacity runoff control program ...is substantially less than the \$65,000,000 10-year capacity combined relief sewer alternative recommended in the 1991 RJN facility plan.*

### ***Study Completed in 1992 Recommending Refined Street Storage***

Wilmette commissioned SEC Donohue (formerly Donohue & Associates) to conduct this preliminary engineering study based on the favorable findings of the previous feasibility study. One change in approach was to use a more sophisticated hydrologic-hydraulic model. The USEPA Stormwater Management Model (SWMM) was now used rather than the Illinois Urban Drainage Area Simulator (ILLUDAS). The principal purpose of SWMM was to represent the dynamics of flow in the system, that is, to rigorously simulate surcharging and backwater effects and the interaction between sewer flows and storage. Also used for the first time in Wilmette was SEC Donohue's

Surface and Street Analysis Model (SASAM). It simulated on-street conveyance and storage of stormwater (SEC Donohue, December 1992, pp. 8-9).

This refined study concluded that a system of street storage and relief sewers could control the 10-year storm for a construction cost of \$31,000,000. The 1999 cost would be \$37 million using the ENR CCI. Thus, this refined study essentially confirmed the preceding study (SEC Donohue, December 1992, p. 9). Details of additional planning, design, financing and construction of the Wilmette street storage system are presented in the remainder of this manual.

### **Observations Regarding Studies to Solve Wilmette's Combined Sewer System Problems**

As with Skokie, a series of studies led to the decision to implement street storage in Wilmette's CSS. Also like Skokie, some of what was learned in the process of conducting the studies might be transferrable to other communities faced with CSS problems. Two observations based on Wilmette's experience are essentially the same as the first two of the three observations presented earlier based on Skokie's experience. They are:

- Occurrence of a series of evolving studies prior to making a commitment.
- Initial focus on traditional solutions.

Wilmette's studies differed from Skokie's in one way: they sought to solve flooding while also reducing the peak discharge from the Wilmette CSS to the MWRDGC system. This gave added impetus, as the studies proceeded, to exploring means to temporarily store stormwater for gradual release. Relief sewers alone would not suffice.

## **CHAPTER 3**

### **THE CONCEPT THROUGH CONSTRUCTION PROCESS FOR STREET STORAGE SYSTEMS**

#### **Status of Urban Stormwater Management**

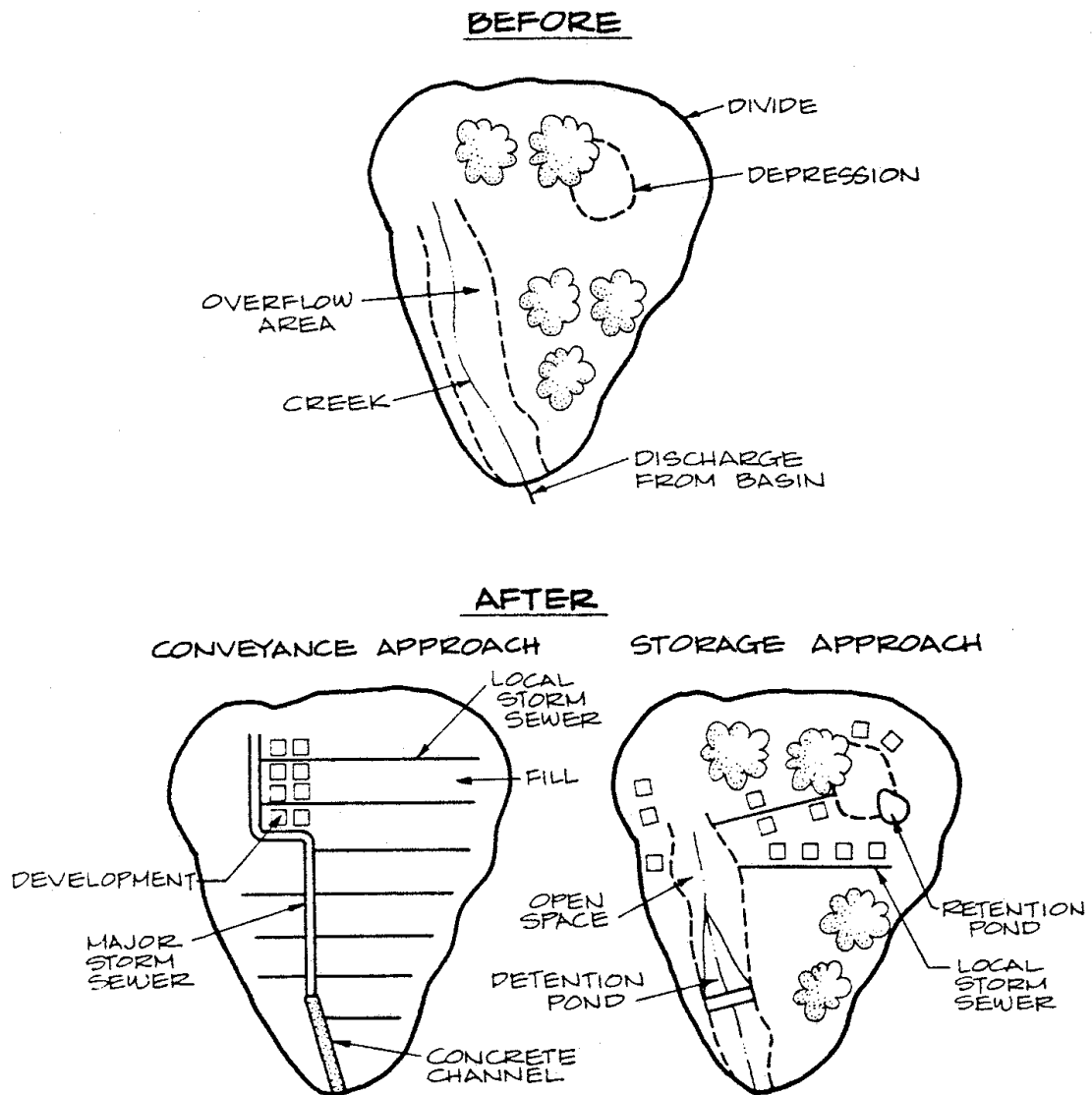
As briefly noted in Chapter 1, the street storage system mitigates surcharging of CSSs by managing stormwater—by reducing peak rates of stormwater before it enters the combined sewer system. Accordingly, a brief review of the status of urban stormwater management, with emphasis on detention, that is, temporary storage of stormwater, is appropriate. The following review is taken from Walesh (1989, pp. 20-31) and other sources as indicated.

#### ***Two Fundamentally Different Approaches: Conveyance-Oriented and Storage-Oriented***

The state of the art of stormwater management has evolved to the point where there are two fundamentally different approaches to controlling the quantity, and to some extent the quality, of stormwater runoff. Using a “before and after” format. Figure 3-1 illustrates selected characteristics of the two available approaches.

#### **Conveyance-Oriented Approach**

The first to the two approaches is the more traditional conveyance-oriented stormwater system. Systems designed in accordance with this approach provide for the collection of stormwater runoff, followed by the immediate and rapid conveyance of the stormwater from the collection area to the discharge point to minimize damage and disruption within the collection area. Principal components of conveyance-oriented stormwater systems are culverts, storm sewers, and channels supplemented with inlets and catch basins.



**Figure 3-1.** Conveyance and storage approaches to stormwater management  
(Source: Walesh, 1989, p. 26).

A potentially effective, newer approach to stormwater control is the storage-oriented system. Its function is to provide for the temporary storage of stormwater runoff at or near the point of origin, with subsequent slow release to downstream storm sewers or channels. This approach minimizes damage and disruption both within and downstream of the site. One or more storage facilities are the principal elements in a storage-oriented system. These principal elements are often supplemented with conveyance facilities, such as culverts, storm sewers, inlets, and catch basins, which transport stormwater to storage facilities and gradually convey flow from those facilities.

### **Comparison of Features**

A principal advantage of the traditional conveyance-oriented approach is applicability to both existing and newly developing urban areas, contrasted with the storage-oriented approach. Storage is more difficult to retrofit into already developed areas because of space limitations. Although retrofitting storage into developed areas is difficult, it is not impossible and it is sometimes cost effective as clearly demonstrated by the Skokie and Wilmette projects.

Other advantages of the conveyance-oriented approach are rapid removal of stormwater from the service area, minimal operation and maintenance requirements and costs, and accepted analysis and design procedures. Principal advantages of the storage-oriented approach are possible cost reductions in newly developing urban areas, prevention of downstream adverse flooding and pollution associated with stormwater runoff, and potential for multiple-purpose uses.

Neither the conveyance-oriented approach nor the storage-oriented approach is inherently better. Both approaches should be considered, at least when a project or development is at the conceptual level.

The conveyance- and storage-oriented approaches to stormwater management are not necessarily mutually exclusive within the same hydrologic-hydraulic system. Depending on the circumstances, the two approaches may be compatible and integrated use of the two approaches may lead to a more optimum stormwater management system. One example of the joint use of the conveyance-oriented facilities in one portion of a watershed and storage-oriented facilities in another portion. Another example of the combined use of the two approaches is to use conveyance-oriented facilities for the convenience system and storage-oriented facilities for the emergency system. The later approach is illustrated by the Skokie and Wilmette projects where the preexisting combined sewers are the convenience system and new street surface storage and underground tank storage constitute the emergency system. The convenience (minor) and emergency (major) systems are discussed in a later section of this chapter.

### ***Historic Development of the Storage-Oriented Approach***

Understanding of the status of stormwater management is informed by its history. Furthermore, to the extent that contemporary use of storage sometimes targets both the quantity and quality of stormwater, that history is very relevant to street storage and possible implication of street storage for control of nonpoint source pollutants. The following historical account is based on Welsh (1989, pp. 29-31) and other cited sources.

The original motivation for using the newer storage-oriented approach over the traditional conveyance-oriented approach was that the former offered cost advantages. Most documented examples of the cost advantage of the storage-oriented approach over the conveyance-oriented approach relate to newly developing areas (e.g., Poertner, 1974). More recently, however, there have been situations in which already developed areas are being retrofitted with a storage-oriented system at significantly less cost than that of a traditional conveyance-oriented system. Examples include the Skokie and Wilmette projects.

A complete comparison of conveyance-oriented and storage-oriented systems for a particular location must consider all costs and benefits, tangible and intangible. For example, reduction in developable land and possible safety hazards to children with the storage-oriented system are costs, while increased land values for areas contiguous to attractive storage facilities are a benefit. Cost analyses must be conducted on a case-by-case basis. Documented case studies and experience suggest that storage facilities should be at least considered for controlling the quantity of stormwater runoff because of the potential for cost savings.

After initial use of storage facilities for the single purpose of controlling the quantity of stormwater runoff, storage facilities found increased use as multiple-purpose developments. In addition to their primary surface water control function, storage facilities were designed to provide, or be part of, sites for recreation including such activities as fishing, boating, tennis, jogging, ski touring, sledding, and field sports. Well-planned, well-designed, and well-operated storage facilities were also found to have aesthetic value for contiguous and nearby residential areas.

In addition to the obvious erosion and sedimentation problems often associated with urbanization, studies conducted in the 1970's indicated that urban stormwater runoff contributes a significant part of some of the pollutants finding their way to surface waters. For example, an early study conducted in Durham, NC, compared the quality of urban runoff with that of secondary municipal sewage treatment effluent on the basis of weight per unit area per year (Colston, 1974). On an annual basis, the urban runoff contributed 91 percent of the chemical oxygen demand, 89 percent of ultimate biochemical oxygen demand, and 99 percent of the suspended solids. Many measures were suggested for controlling urban area nonpoint-source pollution in general and erosion and sedimentation in particular. The use of storage was one of these measures. The state of the art of using storage facilities to control the quality of urban stormwater runoff is still under development.

In summary, storage facilities are being increasingly used for controlling the quantity of runoff because of the cost advantages and because of their recreation and aesthetic values. They are also being increasingly designed to accomplish a third function of controlling the quality of stormwater runoff.

The evolution of using the storage-oriented approach in surface water management is summarized in Figure 3-2. Beginning with the single quantity control function, storage facilities have evolved so that they now can serve three compatible functions: quantity control; recreation, aesthetic, and other supplemental uses; and quality control.

Street storage systems, which make heavy use of storage, have served the quantity control function as demonstrated by the Skokie and Wilmette applications. Street storage also has the potential to serve the quality control function relative to nonpoint source pollution. This possibility is discussed in Chapter 11.

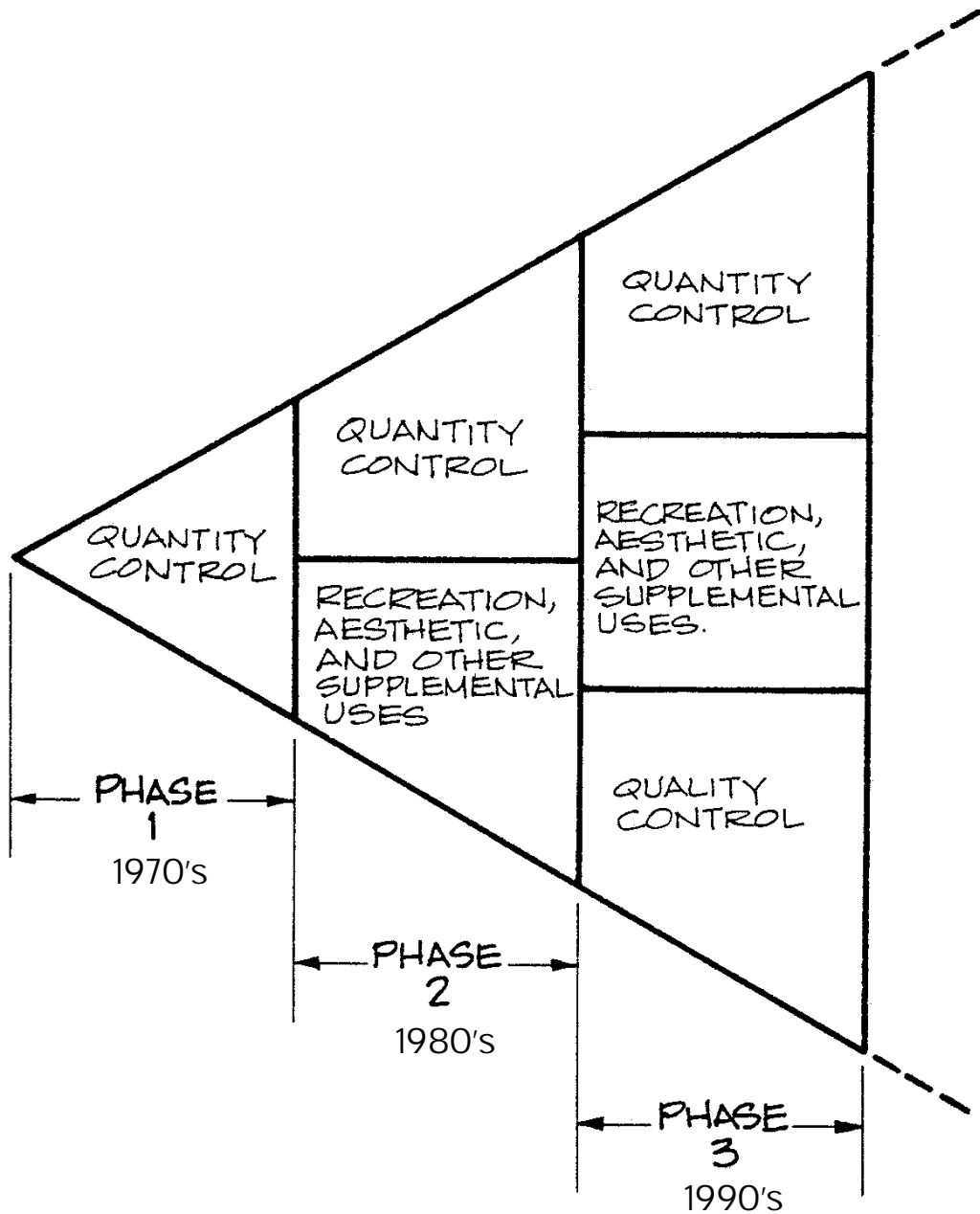
### ***Emergency and Convenience Systems***

The increasingly accepted emergency and convenience system approach to stormwater management is an integral part of the street storage approach. Accordingly, a brief overview of the emergency-convenience system is provided. This overview is taken from Walesh (1989, pp. 31-34) and other cited sources.

The stormwater system may be thought of as two systems, one functionally and physically superimposed on the other. One system, the convenience or “minor” system, contains components that accommodate frequent, small runoff events. The other system, the emergency or “major” or overflow system, consists of components that control infrequent but major runoff events. Although many of the components are common to both the convenience and emergency system, their relative importance in the two systems varies significantly.

#### **The Convenience (Minor) System**

Stormwater systems have traditionally been designed to convey all the design runoff without street flooding, parking lot or other ponding, or basement backup associated with frequent, small runoff events—up to about the five- or 10-year recurrence interval—from an urban area with no damage and little or no disruption or even



**Figure 3-2.** Historic development and use of storage facilities for stormwater management in the U.S. (Source: Walesh, 1989, p. 31).

unimportant.

### **The Emergency (Major or Overflow) System**

Major runoff events—such as 50- or 100-year recurrence interval events—will also inevitably occur in urban areas. Accordingly, some stormwater control systems are designed to control major event runoff rates and volumes in such a manner that although temporary disruptions and inconvenience will occur, widespread danger and damage will be avoided. This is accomplished by allowing for temporary storage and conveyance of stormwater on parking lots and streets, within public open space areas, and in other suitable low-lying areas; by establishing building grades well above street grades; and by designing streets and roadways to serve as open channels providing for the temporary storage and conveyance of runoff as it moves through the urban area toward a safe discharge point.

The emergency system is sometimes called the major system because it is designed to control runoff from “major” rainfall events. Sometimes the emergency system is referred to as the overflow system because it is the system that begins to function when the capacity of the convenience system is exceeded and it overflows.

Most surface water control systems, however, are not explicitly designed to accommodate major runoff events. Nevertheless, major runoff events occur and the emergency system will, by default, function during such events with sometimes catastrophic damage and disruption.

### **Combined Convenience and Emergency System**

The ideal surface stormwater system is planned and designed to include both the emergency and convenience systems in anticipation of the inevitable occurrence of both major and minor runoff events. In a combination system, essentially complete control of minor runoff events is achieved to minimize disruption and damage during smaller, frequently occurring rainfall events. Emergency components of the system are designed to accept some temporary disruption and inconvenience during relatively infrequent events. Jones (1967) provided a very readable and convincing early explanation of the convenience-emergency system concept.

Figure 3-3 illustrates the emergency and convenience system concept applied to a typical urban street cross section. This is essentially the manner in which the emergency system appears in the street storage system described in this report. The variation is that with street storage system, the receiving sewer is a combined sewer—not a separate storm sewer. Figure 3-4 illustrates the emergency and convenience system applied to a channel-floodplain passing through an urban area.

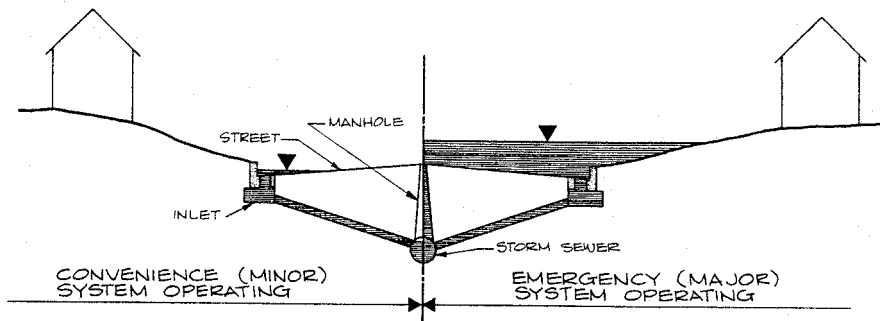
Components in the stormwater system can be examined from the perspective of whether or not they function, how they function, and the relative importance of their

functioning under both convenience and emergency conditions. Consider, for example, stormwater inlets located along the curbs and gutters of urban streets. For minor runoff events, such inlets are normally designed to pass essentially all the discharge conveyed to them, but under major events they should be expected to intercept only a small portion of the flow moving along the gutter. Thus, whereas inlets are key elements in a convenience system, they are of little importance in an emergency system.

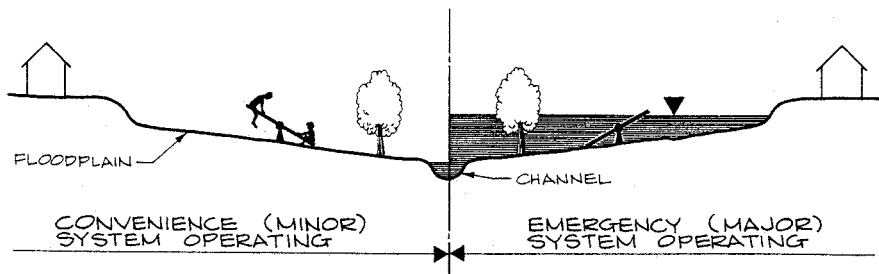
Note, however, that catch basins—inlets with sumps—are of great importance in the Skokie and Wilmette street storage systems. Their operation is not left to chance. Flow regulators are installed in the catch basins.

Streets are graded longitudinally and laterally to provide, during minor runoff events, for rapid runoff of stormwater to curbs and inlets or to roadside ditches. During major events, however, the longitudinal slope of the streets and the relative elevation of the streets and contiguous residences and commercial and industrial structures must be designed such that the street functions as a large, paved open channel or reservoir which temporarily conveys or stores stormwater runoff. Thus, whereas the street is one of many components in a surface water system during minor runoff events, it becomes a key element in the surface water system during major events.

Streets are certainly key elements in the street storage systems described in this report. However, unlike the situation in the design of new development, the basic topography of the streets and contiguous areas is already defined. It provides a physical constraint within which the street storage system must be designed. That design includes some refinements in the topography in the form of street berms.



**Figure 3-3.** Emergency and convenience system applied to an urban street (Source: Welsh, 1989, p. 33).



**Figure 3-4.** Emergency and convenience system applied along a channel and floodplain (Source: Welsh, 1989, p. 33).

Stormwater storage facilities have, as described in the preceding section, proven to be technically sound, economically attractive, and environmentally acceptable elements in urban stormwater management systems. However, they have been used primarily as preventive measures in newly developing areas in contrast with use as remedial measures in developed areas.

Widespread, frequent—one or more times per year—basement flooding is common in existing, old, and intensely developed urban areas, served by CSSs. Traditional and proven remedial measures to CSS basement and surface flooding problems include, as noted in Chapter 1, separation and in-system storage of combined sewage.

A fundamentally different alternative to remedying combined sewer surcharging and surface flooding is retrofitting the existing system to include storage. More specifically, it is feasible under certain conditions to implement a carefully engineered system of surface and sub-surface storage facilities to control the rate at which stormwater flows into the combined sewer system so it does not exceed the capacity of the existing sewers, thereby mitigating basement and other flooding.

The largely implemented Skokie and Wilmette projects have demonstrated the technical and economic feasibility of retrofitting stormwater storage into CSSs. Furthermore, retrofitted stormwater storage can also have other benefits such as reducing peak flows of combined sewage to regional wastewater agencies, mitigating inflow to SSSs, solving flooding problems in separate sewer systems, and managing nonpoint source pollution.

Retrofitting is not limited to CSSs. It can also be applied to the stormwater portion of separate sewer systems for purposes such as improving quantity and/or quality control, reducing safety hazards and enhancing recreation facilities and aesthetic values. Retrofitting stormwater facilities has been explored by and reported on by Welsh (1991, 1992, 1993 and 1998).

### **Distinction Between Analysis and Design: Diagnosis and Then Prescription**

An important integrating theme of this chapter is describing, using mainly case studies, tools and techniques for **analyzing** the root causes of problems in CSSs and **designing** solutions to these problems. A medical analogy helps to appreciate the difference between analysis and design. Analysis in engineering, like diagnosis in medicine, strives to get beyond symptoms. In medicine, symptoms may be a fever or pain. In CSSs, symptoms may be flooded basements or overflows into surface waters. In both medicine and engineering, symptoms may appear to be problems or, in fact, be problems to those who are adversely affected, but they are not the root causes. In medicine, the cause of fever may be an infection and in engineering the cause of a symptom like basement flooding may be inadequate flow carrying capacity of selected sections of combined sewers.

Once the medical diagnosis or engineering analysis has gotten beyond symptoms to causes, remedies or solutions can be explored. Medical doctors prescribe solutions and engineers design solutions.

Walesh (1989, p. 317) elaborates on this two step analysis and design, or diagnosis and prescription, process. His discussion is directly applicable to CSSs. Two fundamental questions must be addressed in all but the most trivial CSSs. First, how does the existing system function, that is, what is the cause or what are the causes of the CSS problems such as basement flooding, surface flooding and CSOs? This, the problem definition phase, must use but look way beyond and below symptoms such as the number of basements flooding, the location of street inundation, and the frequency of overflows. The first step, that is, the analysis or diagnosis phase, focuses on finding causes. A clear understanding of the cause of a problem tends to lead to its solution.

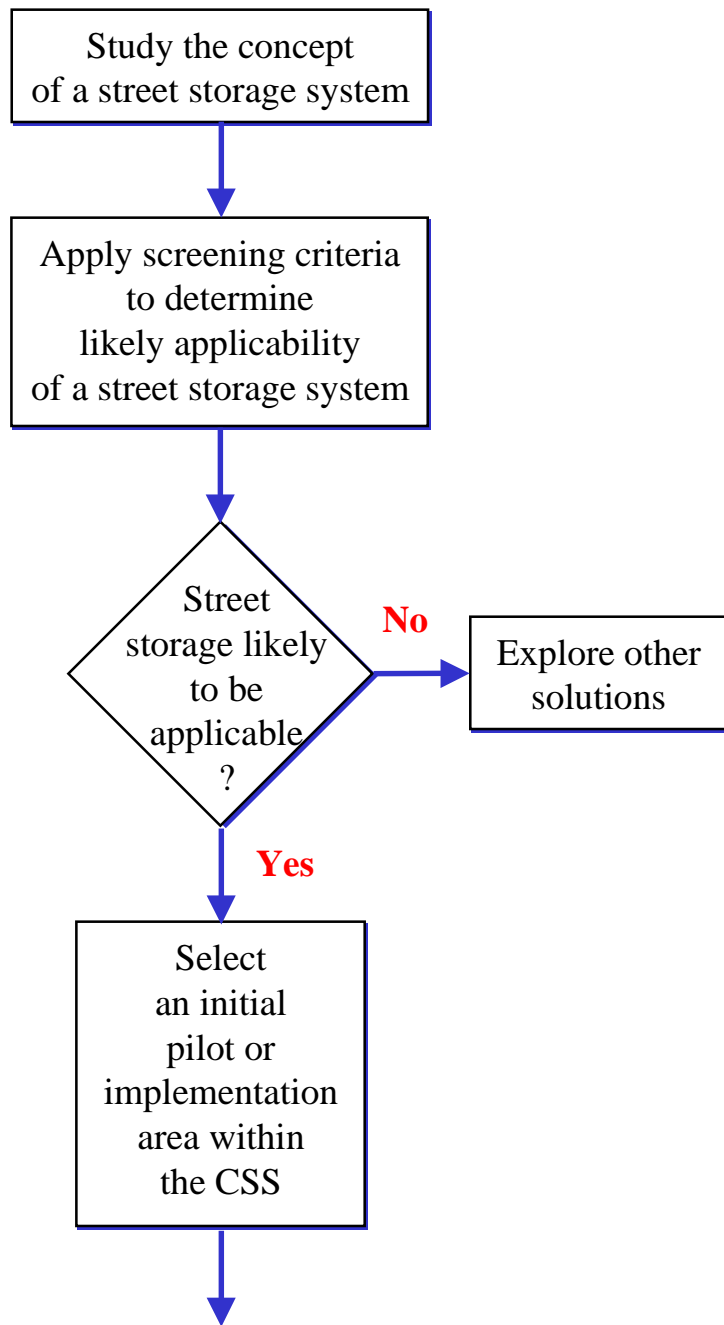
The second fundamental question is: How can the CSS be modified or altered to eliminate or mitigate the causes of the problems and to prevent similar or new problems from occurring in the future? The process of answering this question may be called design or prescription.

Why the emphasis on the two part analysis and design, or diagnosis and prescription process? Answer: CSSs are complex and there is a tendency to rush to judgement as to causes so that a community can “get on” with implementing solutions. Furthermore, there is also a pattern, as shown by the Skokie and Wilmette studies discussed in Chapter 2, to favor, if not exclusively consider, traditional solutions to CSS problems. Superficial analyses combined with a predisposition to employ traditional solutions can lead to unnecessarily costly solutions to CSS problems.

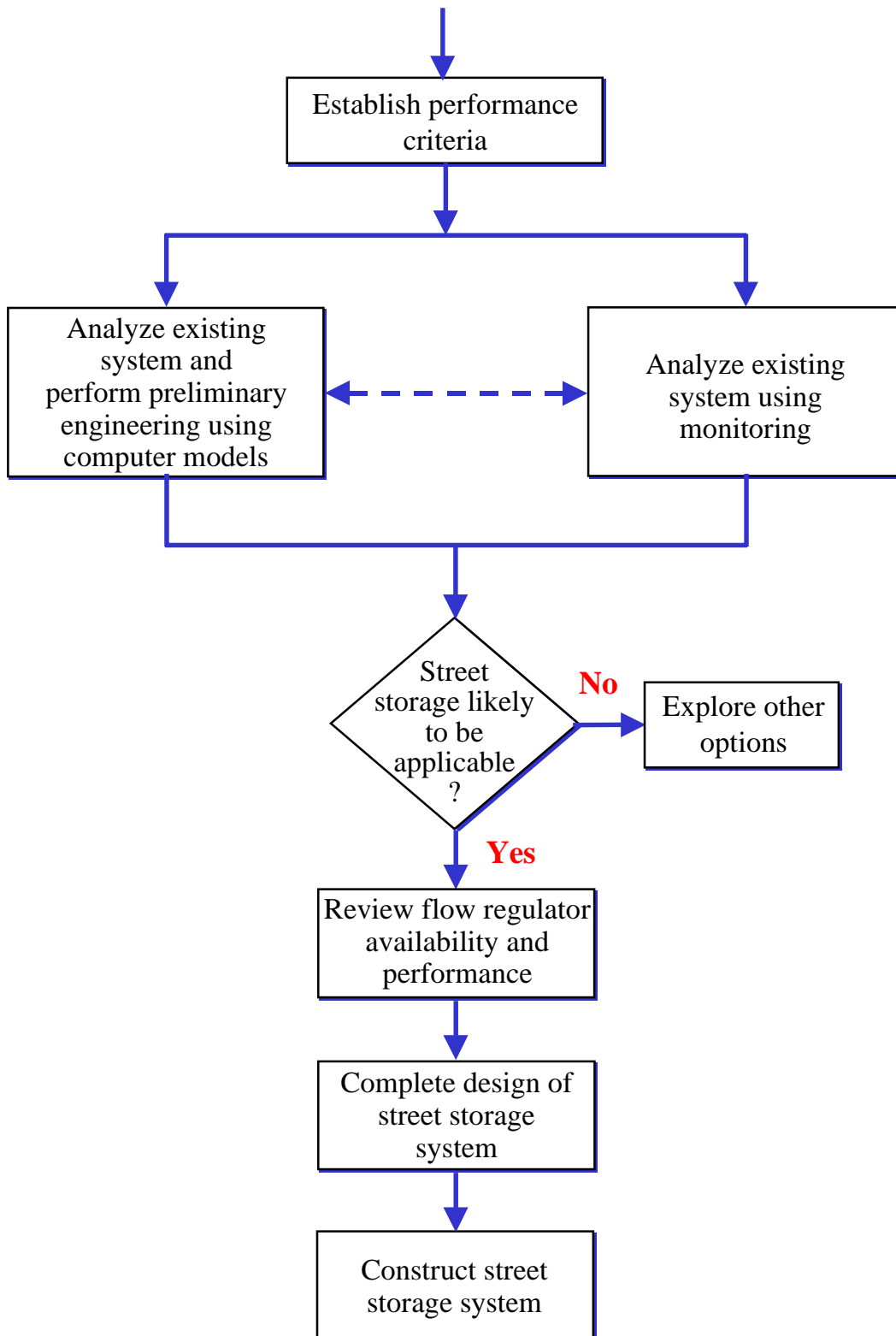
Ideas and information presented in this chapter are intended to show the long term value of a careful, deliberate, multi-faceted (e.g., monitoring, computer modeling, pilot studies) analysis and design process. The “pay off” for a community can be a cost-effective solution to its CSS problems.

### **Chronological Mode of Presentation**

The remainder of this chapter is structured in a chronological fashion. Using Skokie, Wilmette and, occasionally other communities, the steps that may be needed to implement a street storage system are described in the approximate order they would occur. Figure 3-5 illustrates the overall process. The description begins with the understanding of the concept of a street storage system and concludes with



**Figure 3-5 (1 of 2).** Successful application of a street storage system requires a systematic analysis and design process that begins with understanding the concept and concludes with construction.



**Figure 3-5 (2 of 2).** Successful application of a street storage system requires a systematic analysis and design process that begins with understanding the concept and concludes with construction.

constructing the system.

All of the steps followed in Skokie, the first large scale application of street storage, are not likely to be needed in other communities. For example, the laboratory and field testing of various flow regulators that was necessary for the Skokie project would probably not be needed in other applications. However, the Skokie laboratory and field testing is fully described here so that the process and especially the results are available for possible use by others.

## **The Concept of Street Storage**

Fundamental to understanding the street storage system concept is appreciating the capacity of urban streets to carry and store stormwater. Accordingly, this section begins with discussions of the flow capacity and the storage capacity of an urban street. Figure 3-6 shows one photograph of a typical asphalt covered street in Skokie and a typical brick street in Wilmette. These photographs suggest the potential stormwater conveyance and storage functions of urban streets.

### ***Conveyance Capacity of Urban Streets***

Urban streets can be a vital element in the previously described emergency stormwater system by conveying stormwater to a safe discharge point during a major rainfall-runoff event. The Manning open channel flow equation is available for calculating depth versus discharge relationships for urban streets.

## **Street Cross Sections**

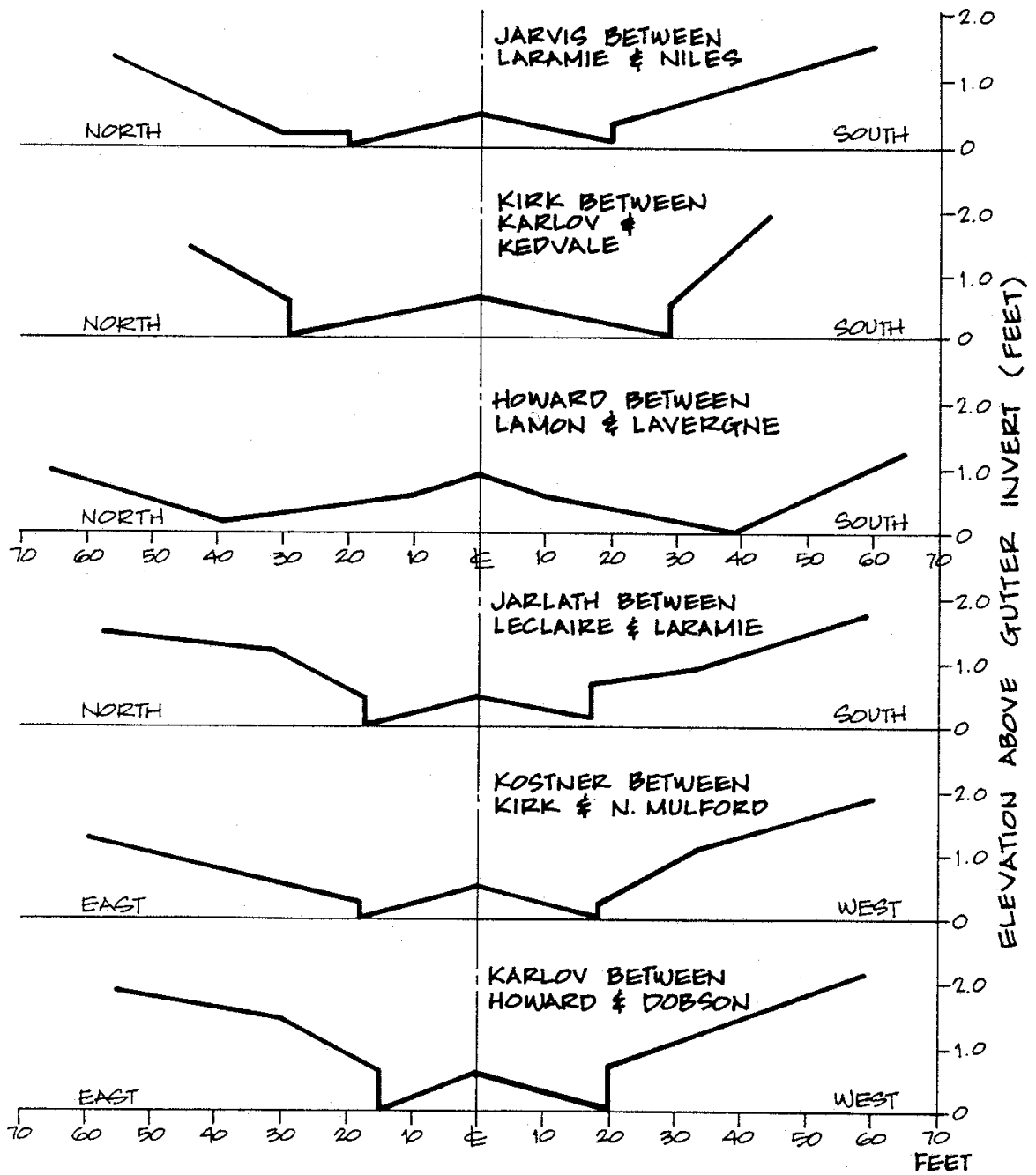
Some Skokie street cross sections, including the adjacent parkway, sidewalk and lawn up to the street side of residences, are shown in Figure 3-7. A typical half cross section of a street, based in part on the configurations of the actual street cross sections shown in Figure 3-7, is presented in Figure 3-8. Longitudinal slopes,  $S_o$ , of 0.1, 1.0, and 3.0 percent are assumed for the subsequent analysis.

## **Analysis Procedure**

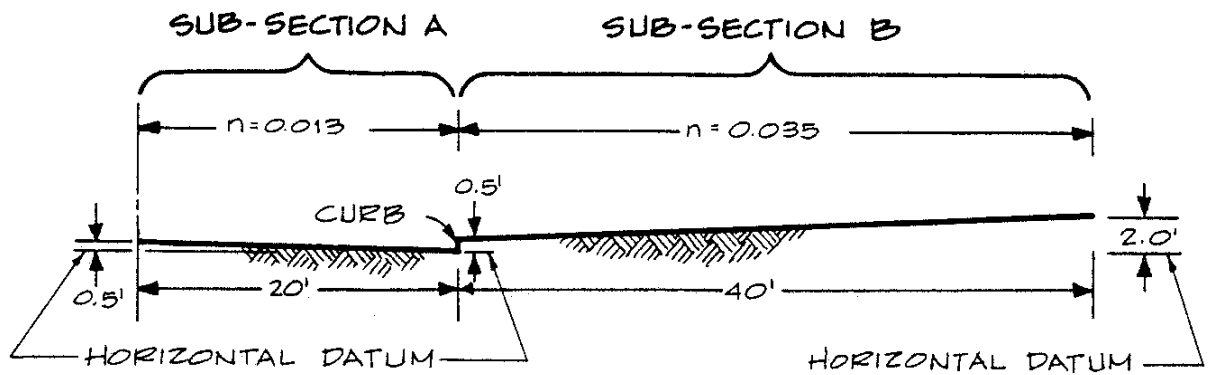
The objective is to determine, assuming normal depth, the flow capacity of the street cross section for a range of depths and a range of longitudinal slopes. The total flow in the half section can be determined as the sum of the flow in subsection A of Figure 3-8, the street portion of the cross section, and subsection B, the lawn portion of the cross section. With this approach, the Manning equation becomes



**Figure 3-6.** The photographs of urban streets in Skokie (top) and Wilmette (bottom) suggest their potential stormwater conveyance and storage function.



**Figure 3-7.** Selected street cross sections from Skokie, IL (Source: Donohue, 1982b, p. 65)



**Figure 3-8.** Typical street and lawn cross section representative of actual Skokie cross sections (Source: Walesh, 1989, p. 191).

$$Q = Q_A + Q_B = 1.49 S_0^{0.5} \left( \frac{A_A R_A^{2/3}}{n_A} + \frac{A_B R_B^{2/3}}{n_B} \right)$$

where

- $Q_A$  = discharge in subsection A
- $Q_B$  = discharge in subsection B
- $S_0$  = longitudinal slope for both subsections (dimensionless)
- $A_A$  = flow cross-section area in subsection A
- $R_A$  = hydraulic radius for subsection A =  $A_A / P_A$ , where  $P_A$  = the wetted perimeter
- $n_A$  = Manning roughness coefficient for subsection A
- $A_B$  = flow cross-sectional area in subsection B
- $R_B$  = hydraulic radius for subsection B =  $A_B / P_B$ , where  $P_B$  = the wetted perimeter
- $n_B$  = Manning roughness coefficient for subsection B

Assume the depth of flow at the gutter of 0.5 ft. Then

$$A_A = (0.5)(0.5)(20) = 5 \text{ ft}^2$$

$$P_A = 0.5 + (20^2 + 0.5^2)^{0.5} = 20.5 \text{ ft}$$

$$R_A = \frac{5}{20.5} = 0.244 \text{ ft}$$

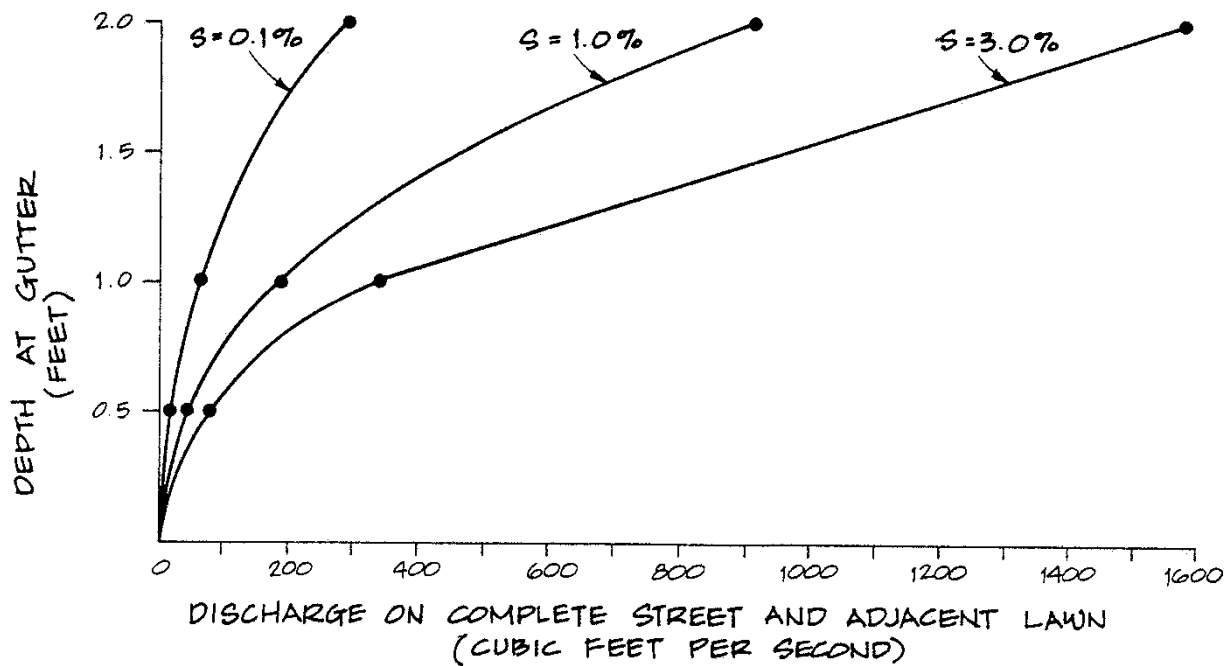
$$A_B = 0$$

$$Q = Q_A + Q_B = 1.49 S_0^{0.5} \frac{(5 \times 0.244^{2/3})}{0.013} + 0 = 224 S_0^{1/2}$$

Substituting  $S_0 = 0.1$ ,  $1.0$ , and  $3.0$  percent yields half-street discharges of 7.1, 22.4, and 38.8 ft<sup>3</sup>/sec, respectively. The corresponding average velocities are, 1.42, 4.48, and 7.76 ft/sec, respectively. The preceding process is repeated for depths at the gutter of 1.0 and 2.0 ft.

## Results

Depth versus discharge relationships for the complete street cross section, including adjacent lawns, are summarized in graphic form in Figure 3-9. A separate curve is presented for each of the three longitudinal slopes.



**Figure 3-9.** Depth versus discharge relationships for typical street and lawn cross sections (Source: Walesh, 1989, p. 192).

The analysis indicates that streets can carry very large flows relative to typical storm sewers at similar slopes. For example, consider the case with a depth at the gutter of 1.0 ft. For the three longitudinal slopes, flows on the full width of street and adjacent lawn areas are approximately 14 to 18 times greater than those that would be carried in a 24-inch diameter reinforced-concrete pipe laid at the same slope and flowing full.

The preceding analysis suggests that better use could be made of streets by designing them to be channels that function as part of the emergency stormwater system. Using streets for temporary stormwater conveyance is one aspect of the street storage system.

### ***Storage Capacity of Urban Streets***

Urban streets can also constitute a vital element in the emergency stormwater system by temporarily storing stormwater until it can be safely discharged to storm or combined sewers. Actual street cross sections shown in Figure 3-7 suggest the volume of storage available.

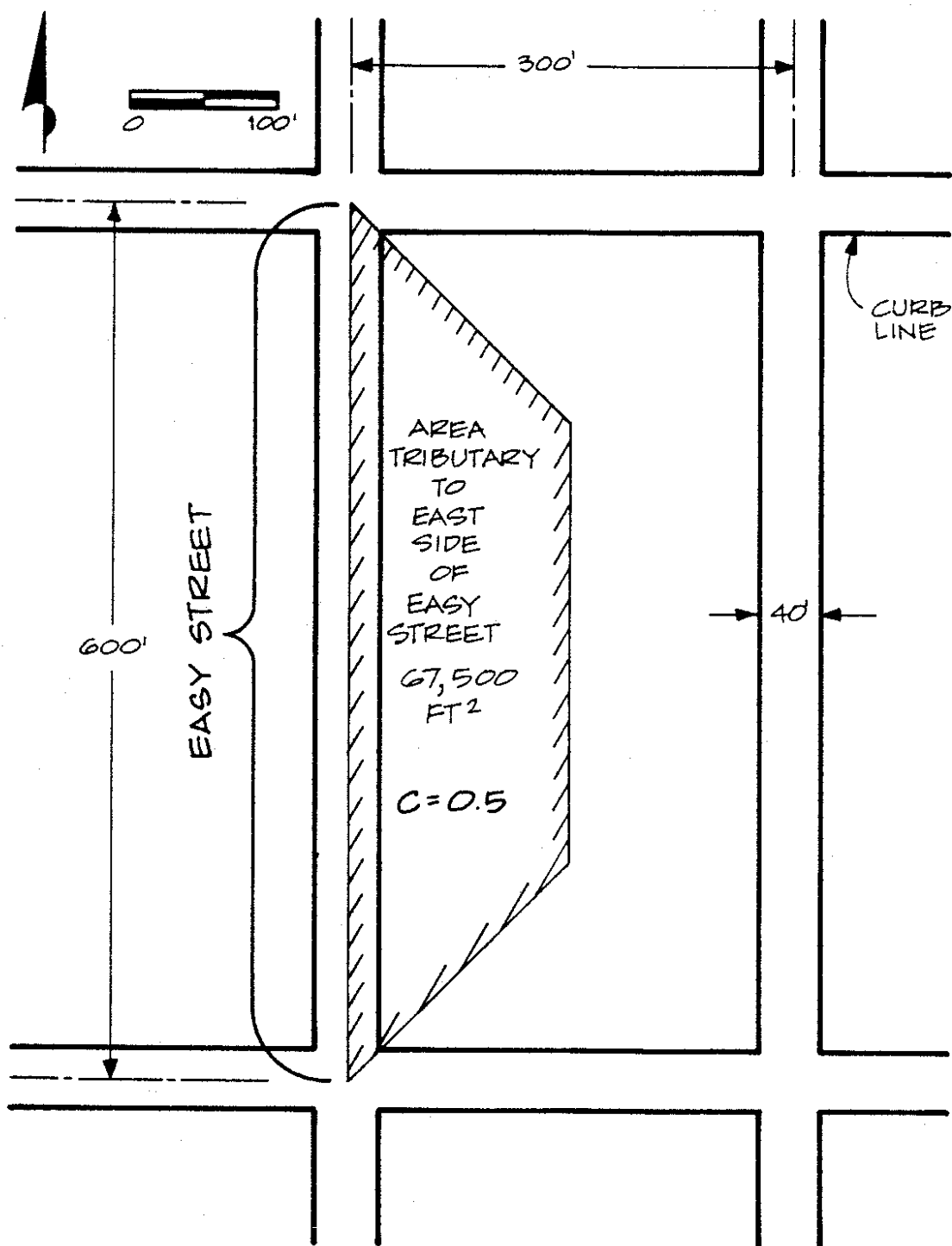
### **Analysis Procedure**

Consider again the typical street cross section presented in Figure 3-8 and cross sectional areas calculated and presented in the previous section titled “Conveyance Capacity of Urban Streets.” A plan view of a typical single-family residential area with paved streets and curb and gutter is shown in Figure 3-10.

Consider the east half of the 600-ft-long section of Easy Street and the directly tributary area of 67,500 ft<sup>2</sup>. The runoff coefficient for the area is 0.5; that is, half of the rainfall on the total tributary area is directed toward the east half of Easy Street.

Assuming that the street has a zero longitudinal slope, the cross-sectional area of the east side of the street and cumulative storage on the east side of the street may be calculated as a function of depth of water relative to the gutter. Results are presented in Table 3-1 and Figure 3-11. The depth versus volume relationship for the east side of the 600-ft-long street has a shape similar to the depth versus volume relationship for a natural river valley. That is, as depth increases, the relative volume of incremental storage per unit of depth increases at least over the first one foot of depth.

Assume rainfall amounts of 0.5, 1.0, 2.0, and 4.0 in., which may be typical of moderate to very severe rainfall events. Assuming that half of the rainfall is directed to and remains in the street, the depth versus storage relationship presented in Figure 3-11 can be used to determine the depth of ponded water for each rainfall amount. The results are presented in Table 3-2.



**Figure 3-10.** Typical urban street plan showing the area tributary to the east side of a one block segment of Easy Street (Source: Welsh, 1989, p. 193).

**Table 3-1.** Depth, cross-sectional area, and cumulative volume data for half of Easy Street (Source: Walesh, 1989, p. 194).

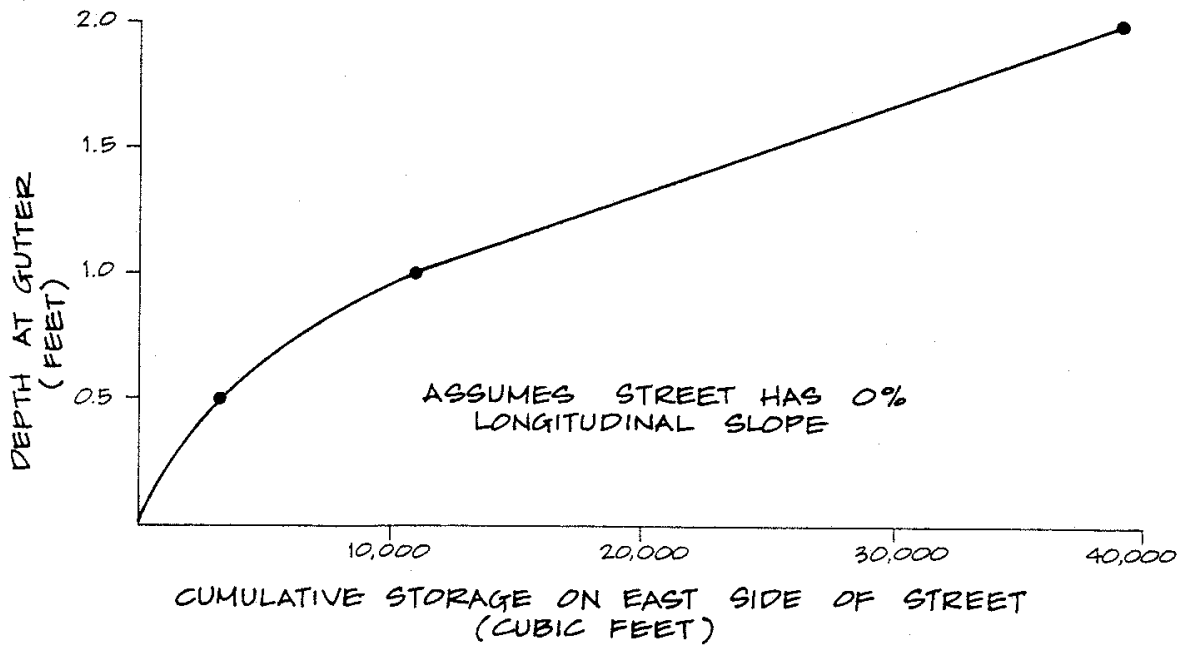
Depth at Gutter (ft)	Cross-Sectional Area on East Side of Street (ft <sup>3</sup> )	Cumulative Storage on East Side of Street <sup>1</sup>	
		(ft <sup>3</sup> )	(acre-ft)
0.0	0.0	0	0
0.5	5.0	3,000	0.07
1.0	18.33	11,000	0.25
2.0	65.00	39,000	0.90

1) for 600-ft. street segment and assuming zero longitudinal grade.

**Table 3-2.** Rainfall and depth of ponding for Easy Street<sup>1</sup> (Source: Walesh, 1989, p. 194).

Rainfall (in.)	Runoff		Depth of Ponding in Street Relative to Gutter (ft.)
	(in.)	(ft <sup>3</sup> )	
0.50	0.25	1,410	0.30
1.00	0.50	2,810	0.45
2.00	1.00	5,625	0.75
4.00	2.00	11,250	1.00

1) Assumes zero longitudinal grade.



**Figure 3-11.** Depth versus volume relationship for Easy Street and lawn cross section (Source: Walesh, 1989, p. 194).

## Results

As indicated, even with four inches of rainfall, and assuming that two inches of runoff is stored in the street, the peak depth of street ponding relative to the gutter would be one foot.

The simple analysis suggests that streets with low longitudinal grades have the capacity to store large volumes of stormwater runoff. Situations may arise where new streets can be designed to store stormwater, or existing streets can be retrofitted to serve a storage function as part of the emergency system. The latter retrofitting idea is one aspect of the street storage system.

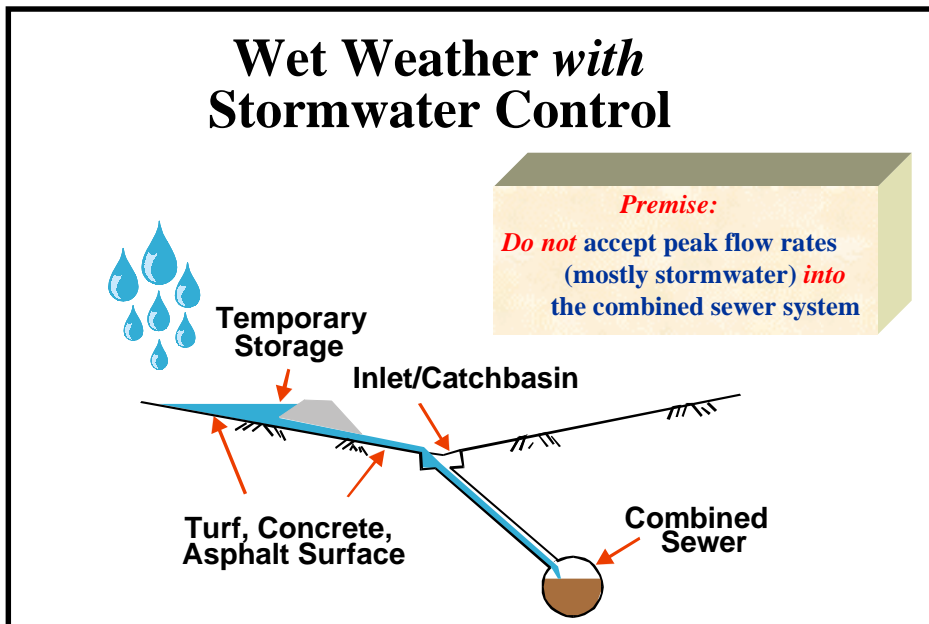
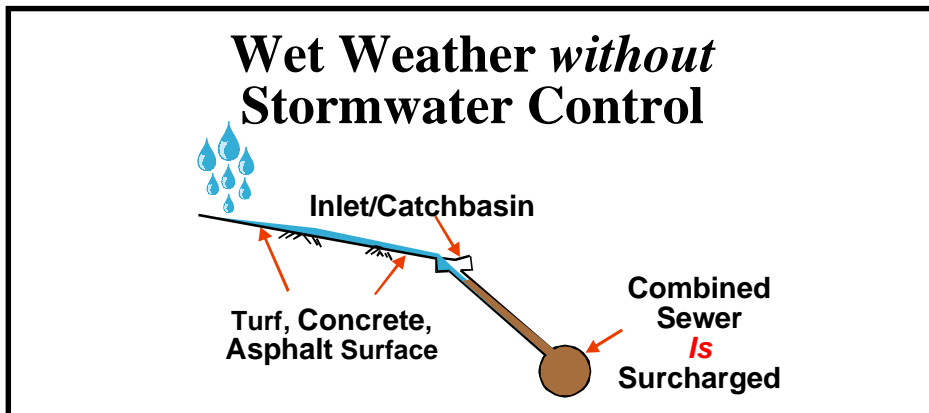
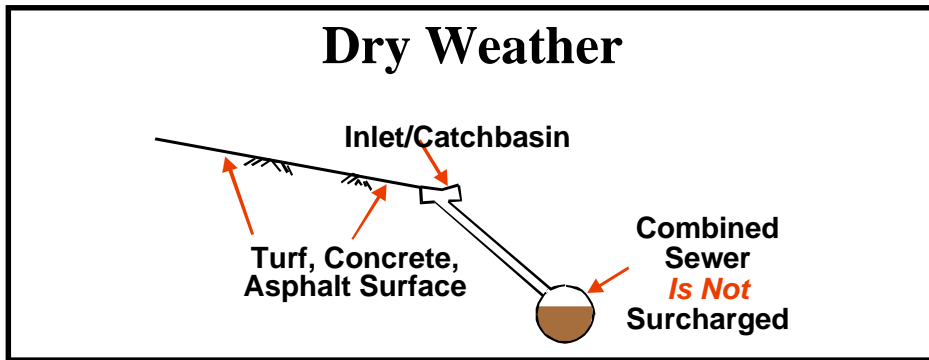
### ***Using Street Storage and Conveyance Capacity in Combined Sewer Systems***

Attention now turns to CSSs. As briefly noted in Chapter 1, wet weather problems in CSSs, such as basement flooding, street flooding, and CSOs, are caused by peak rates of stormwater runoff, not necessarily by the runoff volumes. Midwestern experience suggests that wet weather flooding and pollution problems would often not occur, or would be much less severe, if the peak flows of stormwater could be lessened. Peak flows are often the principal culprit, not the volumes of stormwater runoff.

This suggests a fundamentally different approach having the following premise: reduce the peak flow rates of stormwater before it enters the combined sewer system. Accept the full volume of stormwater into the stormwater runoff into the CSS, but greatly reduce the peak rate of entry. Figure 3-12 illustrates, in conceptual fashion, this stormwater-oriented approach to reducing surcharging in CSS and, therefore, mitigating flooding and pollution.

But where and how can stormwater runoff be temporarily stored and otherwise controlled to reduce peak flows into the CSS? Urban streets have significant storage and conveyance capacity, as just illustrated, in this chapter. That storage capacity and conveyance capacity can be effectively utilized to answer the question of where and how to temporarily store stormwater.

Because of their storage capacity, some streets can be used to temporarily store stormwater before it mixes with sanitary sewage and surcharges the CSS. Because of their conveyance capacity, other streets can be used to convey stormwater from street segments with low surface storage capacity to street segments with high surface storage capacity. Streets in effect become a rectilinear conveyance and storage system that are activated under emergency conditions, that is, when the capacity on one or more segments of the CSS is exceeded.



**Figure 3-12.** Control of peak rates of stormwater runoff can, in concept, mitigate surcharging of combined sewer systems.

## **Bringing the Street Storage Concept to Reality: Berms, Flow Regulators, and Subsurface Storage**

Capitalizing on street storage and conveyance capacity requires three elements that operate in an integrated fashion. These elements are berms, flow regulators and subsurface tanks. In this section, first berms and then regulators are described. Their integrated function is then explained. Finally, subsurface storage facilities, which also use regulators, are discussed.

### ***Berms***

#### **Berms Contrasted With Bumps and Humps**

A berm is a low structure constructed across a street, from curb to curb, and intended to temporarily impound water on its upstream side. The crest or top of the berm, when viewed along the longitudinal axis of the street, is horizontal. It is, in effect, a spillway.

Figure 3-13 is a photograph of a mid-block berm in Skokie. The berm is identified by the asphalt overlay. A berm that lies across a Skokie intersection is shown in Figure 3-14. This berm may also be identified by the asphalt overlay. A berm under construction is shown in Figure 3-15. The construction process typically consists of:

- Relocating inlets, if needed.
- Raising the curb and gutter, which has been done in Figure 3-15.
- Milling the street surface. The concrete has been milled in Figure 3-15.
- Placing lifts of asphalt to form the berm. At least one lift has been placed in Figure 3-15.

The term berm was selected early in the Skokie street storage project to distinguish it from bumps and humps, two established types of vehicle speed control devices. The essential features of bumps, humps and berms are illustrated in Figure 3-16.

According to the Institute of Transportation Engineers (1997, p. 1):

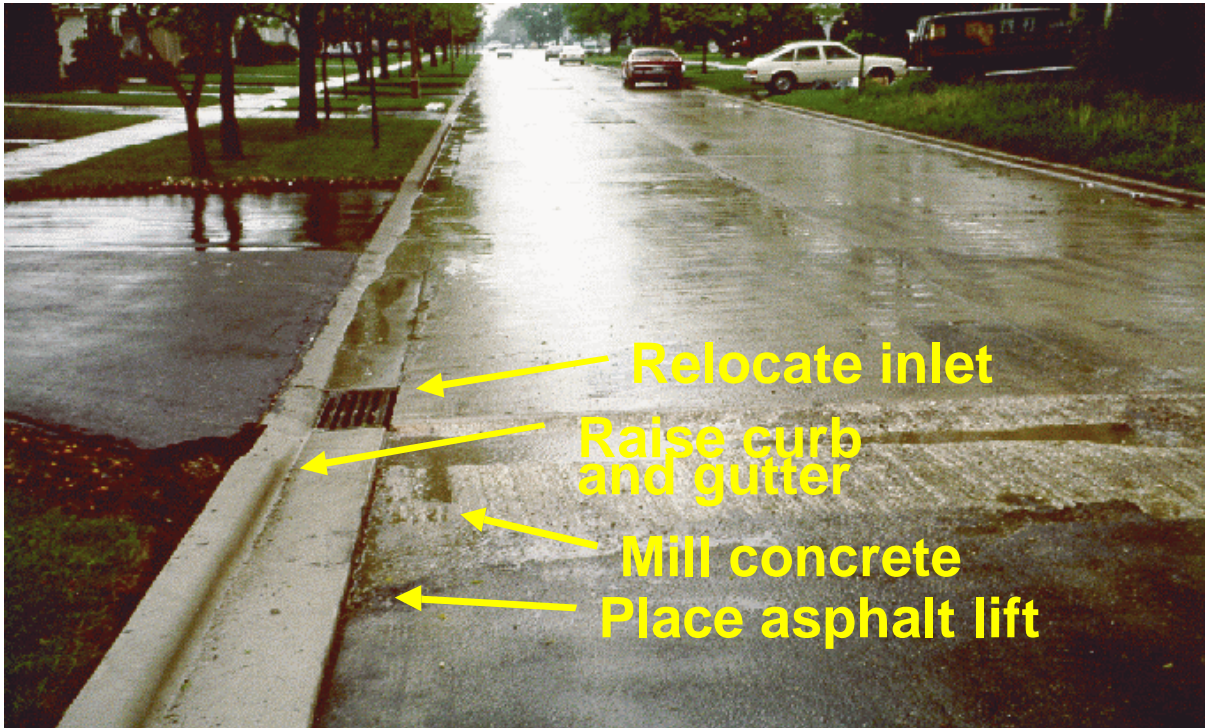


**Figure 3-13.** Mid-block berm in Skokie intended to direct the flow of stormwater runoff.



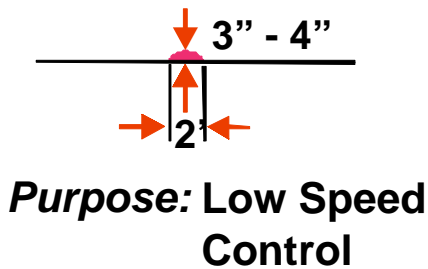
***Purpose:***  
**Temporarily  
store  
stormwater**

**Figure 3-14.** Berm across an intersection in Skokie.

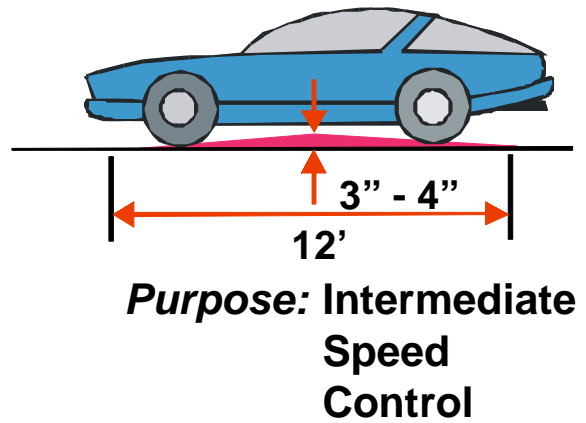


**Figure 3-15.** A berm under construction in Skokie showing relocated inlet, raised curb and gutter, milled concrete surface and an asphalt lift.

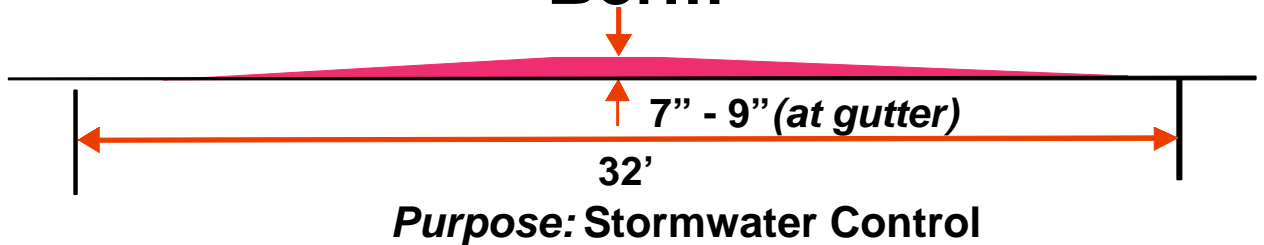
## Bump



## Hump



## Berm



**Figure 3-16.** Bumps and humps are vehicle control devices and the gentler berm is a stormwater control device.

*of three to six inches with a length (in the direction of vehicle movement) of one to three feet. Speed bumps are typically found on private roadways and parking lots and do not tend to exhibit consistent design parameters from one installation to another... A bump causes significant driver discomfort at typical residential speeds and generally results in vehicles slowing to five mph or less at the bump.*

Also, according to the ITE (1997, p. 1):

*A speed hump is a raised area in the roadway pavement surface extending transversely across the travel way... speed humps normally have a maximum height of three to four inches with a travel length of approximately 12 feet... Within typical residential speed ranges, humps create a gentle vehicle rocking motion that causes some driver discomfort and results in most vehicles slowing to 15 mph or less at each hump and 25 to 30 mph between properly spaced humps in a system.*

Some speed humps have a flat top, that is, a plateau shape with gradual approaches on both ends. This configuration tends to protect long wheel base vehicles like fire trucks (Velazquez, 1992). Recognizing that speed humps control vehicle speeds without the presence of police personnel, the humps have been called “sleeping policemen” (ITE, 1997, p. 1).

In the interest of more fully understanding speed humps, consider their benefits and drawbacks, as noted by Elizer (1996), and Haynes (1998). Some of these positive and negative features can also be applied to berms when they are viewed from a vehicular perspective.

Principal speed hump benefits are:

1. Reduced vehicle speeds.
2. Less accidents.

3. Diversion of traffic to more desirable routes; for example, from a local street being used as a short cut to an arterial street.
4. Less traffic noise with the possible exception of more noise from trucks.
5. Less air quality impact and energy use than stop signs.
6. Support by most local residents.

Some speed hump drawbacks include:

1. Undesired traffic diversions; for example, from arterial to local streets.
2. Interference with the rapid response of police, firefighters, paramedics and other emergency vehicles.
3. Negative aesthetic impact of humps and related signs and markings.
4. Concern with street sweeping and plowing, ice formation and other maintenance and repair functions.
5. Fear of increased liability exposure attributed to claims of vehicle damage and injury to bicyclists.
6. Poor design and construction resulting from the misperception that humps are simple. ITE (1997) provides detailed design guidance.

Given the possible benefits and drawbacks to speed humps, some municipalities have taken a systematic approach to optimize their use. During the 1994 to 1997 period, 217 people were killed in automobile crashes in Montgomery County (Haynes, 1998). Accordingly, the county installed more than 1000 humps on 300 residential streets as a partial solution to the excessive number of automobile accidents. Thousand Oaks, CA, which is one of the first U.S. cities to use speed humps, installed them and studied their effects. Their conclusion: if the hump is more than two inches high, drivers will seek alternate routes (Velazquez, 1992). Boulder, CO addressed the issue of interference with emergency vehicles by banning speed humps on emergency routes (Haynes, 1998).

### **Berms: The Negative Perception Problem**

The suggestion of building structures across streets to control stormwater often elicits negative reactions, especially from engineers and other personnel responsible for the design, construction and maintenance of streets. The driving public may also express concern. One way to deal with this is to note that across street structures are commonly used in urban areas to control the speed of vehicles. For example, ITE (1997, p. 5) provides a “partial listing of jurisdictions with speed hump experience” in the United States and Canada. Included in the partial list are 52 communities in 17 states and three provinces. (ITE (1997, p. 5) also notes that speed humps are also used in at least 14 countries outside of the U.S. In other words, humps, engineered cross-street structures, are widely used in the transportation field.

Note that a berm has a much gentler slope than a hump in the direction of travel.

Accordingly, berms cause even less discomfort than humps. Clearly, berms are vastly different than bumps when measured in terms of driver discomfort.

### **The Possibility of Integrating Stormwater Berms and Speed Hump Functions**

Although the berms, as used extensively in Skokie and Wilmette, differ markedly in function from the humps used widely in traffic control, berms and humps are very similar in form. This suggests that traffic engineers and other personnel responsible for urban streets should be receptive to the idea of using berms to control stormwater. In fact, the convergence of the stormwater berm and the speed hump suggests the possibility of retrofitting existing urban areas with these simple structures for the dual purposes of stormwater and traffic control. Going one step further, convergence of the form and function of berms and humps opens the possibility of designing these structures into new urban development to optimize stormwater and traffic management.

The previously mentioned ITE (1997) document is described as a recommended practice of the ITE. Interestingly, the only mention of stormwater in this document is a brief caution to not interfere with drainage. More specifically, ITE (1997, p. 20) states:

*Speed humps should be installed with appropriate provisions made for roadway drainage... Ideally, a hump should be installed immediately on the downside of an existing drain inlet. If this is not feasible the construction of a bypass drain or other treatment to route water around the hump should be considered.*

On the more positive side, and in keeping with the idea integrating stormwater berms/speed hump structures into new development, ITE notes that speed humps could be designed into new streets. The guidelines state (ITE, 1997, p. 27):

*It is desirable in the planning of new residential subdivisions to configure and design local streets to minimize excessive speed, excessive volumes, and cut-through traffic from outside the immediate neighborhood. However, where adequate subdivision planning and street design control cannot be achieved, and one of the aforementioned problems is considered likely, it may be appropriate to include speed humps as part of new street construction after consideration of less restrictive design or traffic*

control techniques.

### **Flow Regulators**

For purposes of this manual, a flow regulator is a passive, gravity device that regulates the flow of stormwater into a combined sewer. Because it restricts flow, a flow regulator must be designed in combination with storage which is usually located immediately upstream.

Donohue (March 1984a, p. 3-1) identifies three common features of flow regulators:

*A common feature of flow regulators is that they are gravity devices operating without external energy sources or external control. That is, they are intended to be simple devices requiring no control and minimal attention.*

*A second characteristic shared by most flow regulators is that they are designed and installed to achieve the desired flow reduction while minimizing the likelihood of blockage by debris relative to that which could occur with a conventional orifice. Some flow regulators result in less flow passing the control section for a given head or head range than would occur with a simple orifice.*

*A third feature of flow regulators is the need to specify three parameters for design. The first parameter is the maximum discharge and the second parameter is the corresponding design head. The third parameter is installation requirements such as available space and expected orientation of the device.*

Many flow regulators have been developed and tested. A discussion of the configuration and performance of various flow regulators appears later in this chapter. For the purposes of this section, flow regulators are viewed as a generic device having the preceding three features.

As further explained by Donohue (March 1984a, p. 3-1), “flow regulators may be installed in a variety of locations in an urban stormwater-wastewater system including: in storm inlets and catch basins to cause temporary ponding on streets or in depressed

areas; at the outlets of subsurface and surface detention facilities to induce temporary subsurface and surface storage; and within ...sewers to utilize available in-system storage.”

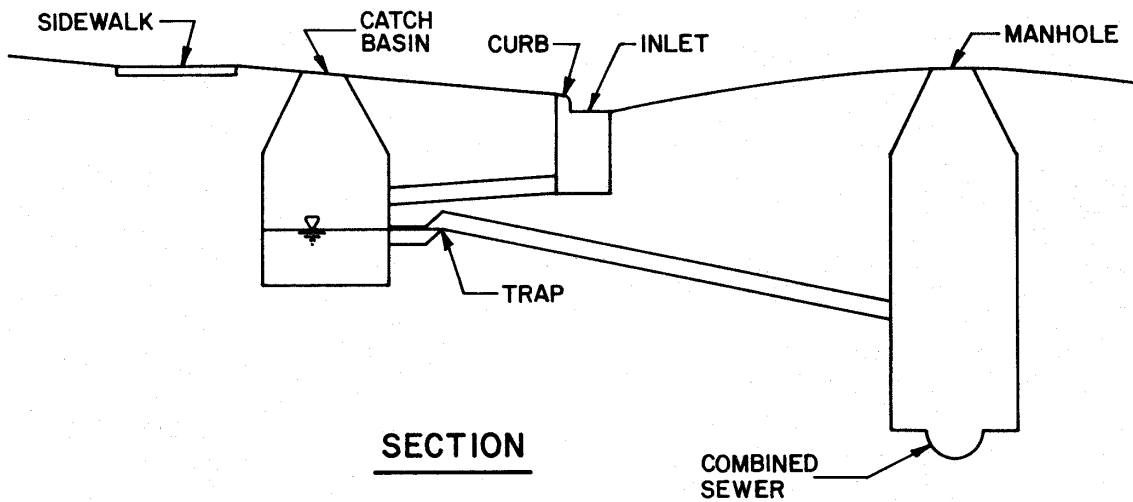
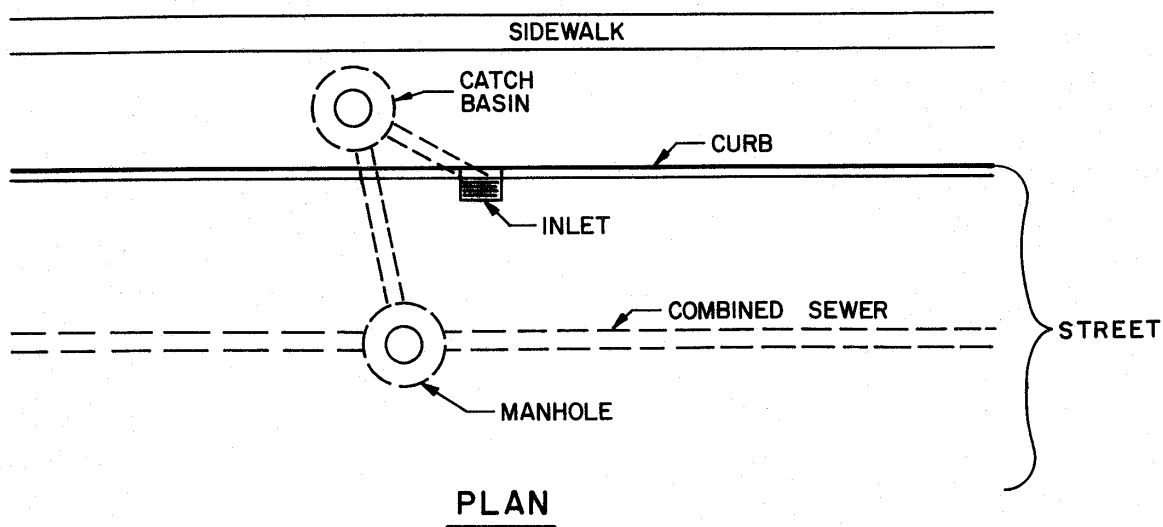
The meaning of the terms inlet and catch basin, as used for example in the preceding paragraph, are important for purposes of this report. As explained by Donohue (March 1984a, p. 3-1):

*Inlets collect runoff from the land surface and discharge via a pipe. Inlets do not have a sump. That is, the discharge pipe is at the bottom of the inlet. Catch basins receive flow from inlets and, occasionally, directly from the land surface and discharge to the sewer system. Catch basins have a sump created by the outlet pipe being several feet above the bottom of the basin. This sump serves to trap leaves and other debris and requires periodic removal and cleaning.*

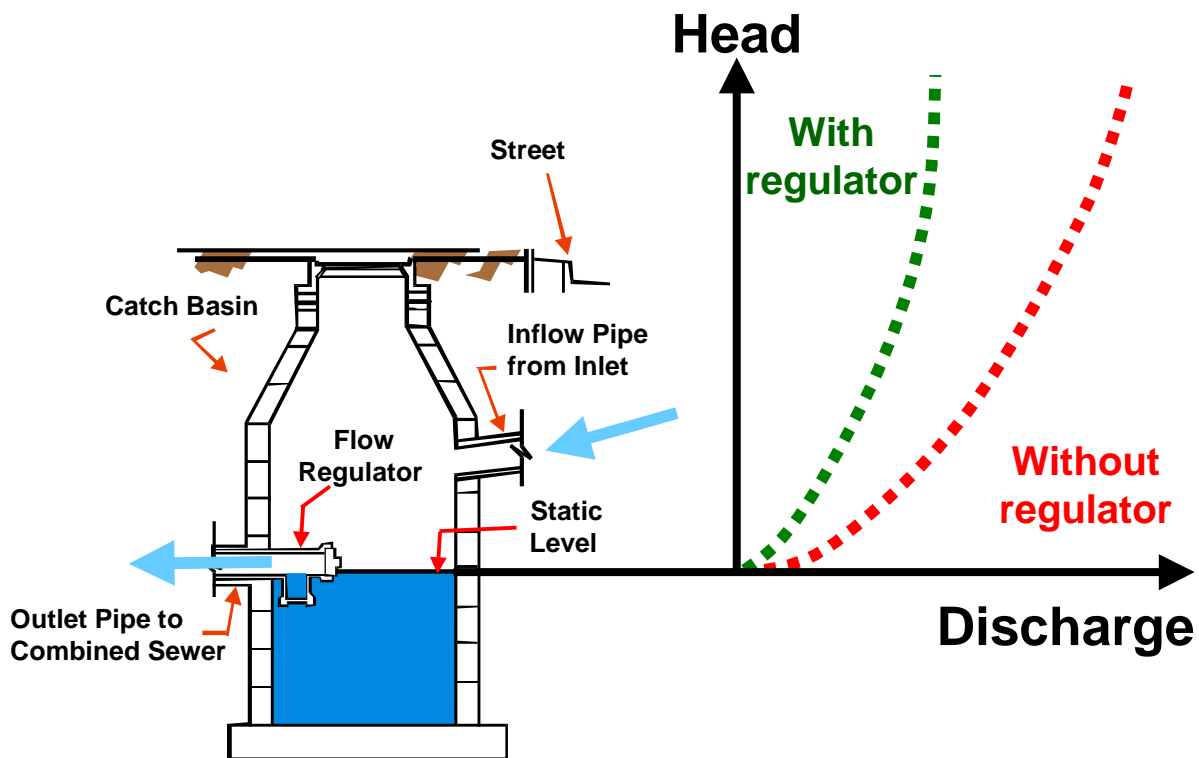
A typical Skokie configuration of an inlet, a catch basin and a manhole on a combined sewer is shown in Figure 3-17. The configuration is shown in plan and section. Note that, in a properly operating system, the transition from stormwater runoff to combined sewage occurs in the pipe connecting the catch basin to the manhole. A trap, as shown in Figure 3-17, is required to prevent sewer gases from being a problem near the catch basins.

Figure 3-18 uses a flow regulator installed in a catch basin to illustrate the regulator's function. Comparison of the two head-discharge relationships indicates that for any given head on the catch basin outlet, the flow regulator results in significantly less flow out of the catch basin. This flow restriction or reduction must be accomplished without blocking of the flow regulator with debris carried by the stormwater.

Although the function of a flow regulator is illustrated in Figure 3-18 using a catch basin installation, flow regulators can be installed in other places. Example locations, as noted earlier, are in stormwater inlets and at the outlets of surface and subsurface storage facilities.



**Figure 3-17.** Typical configuration of an inlet, catch basin and manhole in the Skokie combined sewer system (Source: Donohue, March, 1984a, p. 3-2).



**Figure 3-18.** A flow regulator installed in a catch basin illustrates the basic function of the regulator.

In Wilmette's CSS, a pair of special catch basins were constructed immediately upstream of berms and fitted with flow regulators. These catch basins were connected to a single new manhole on the adjacent combined sewer. In some cases, as described in the Chapter 9 section titled "Summary of Interviews with Wilmette, IL Officials," shear gate flow regulators were placed at the downstream end of pipes connecting the catch basins to the combined sewer manholes.

In summary, suitable catch basins and manholes already existed in Skokie and the catch basins needed only to be fitted with flow regulators. Existing inlets often had to be moved or new ones installed. In Wilmette, new catch basins, which also served as inlets, had to be constructed as did new manholes on the adjacent combined sewer.

### ***Combined Function of Berms and Flow Regulators.***

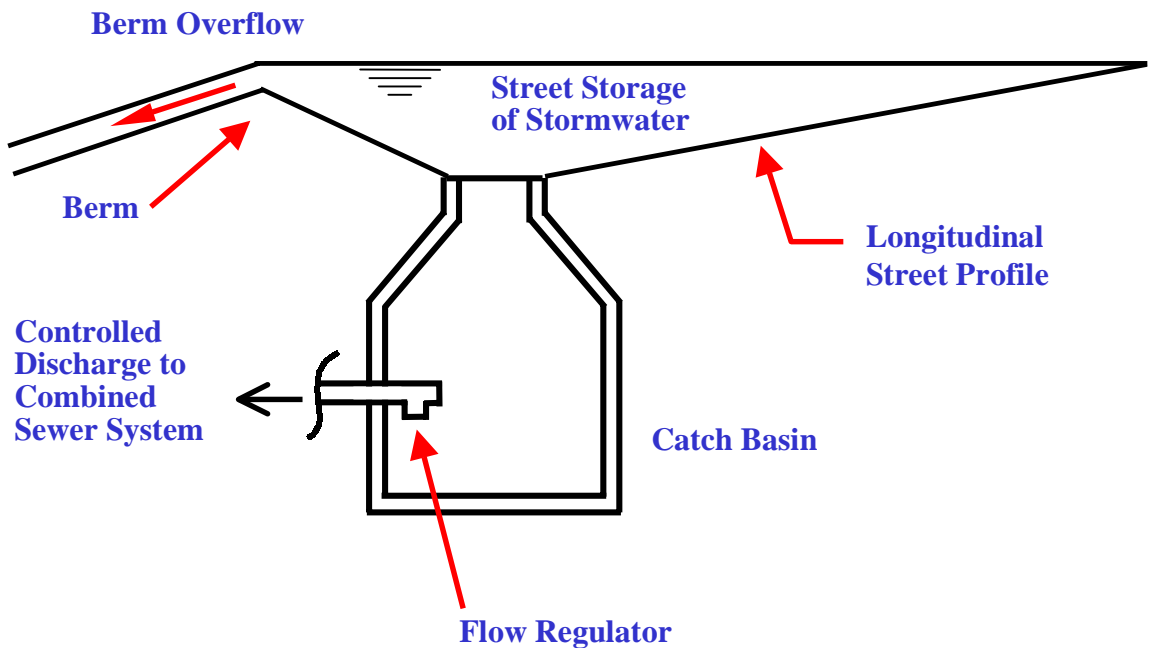
Functioning together, berms and flow regulators become, in what more traditional stormwater management is called, an outlet works. The berm-flow regulator combination, like the outlet works on a traditional stormwater detention basin, is sized and configured to temporarily store stormwater to achieve a desired attenuation of the stormwater runoff hydrograph.

Figure 3-19 shows how a berm on a street and a flow regulator in a catch basin cause temporary ponding of water on the street during and immediately after a runoff event. During and immediately after the event, the peak flow from the catch basin is limited, by the design of the flow regulator and the berm, to what can be conveyed by the receiving combined sewer without surcharging. After, the event, the temporarily stored water drains by gravity through the catch basin.

Figure 3-20 takes the description of the combined function of berms and flow regulators one step further. Shown here is a hypothetical profile, with great vertical exaggeration, along the longitudinal axis of a street. Berms and flow regulators (the flow regulators are not shown) are strategically placed to take advantage of the storage capacity along the length of the street. Low points, which are also storage areas, are used with peak outflow of stormwater to the CSS also being governed by flow regulators.

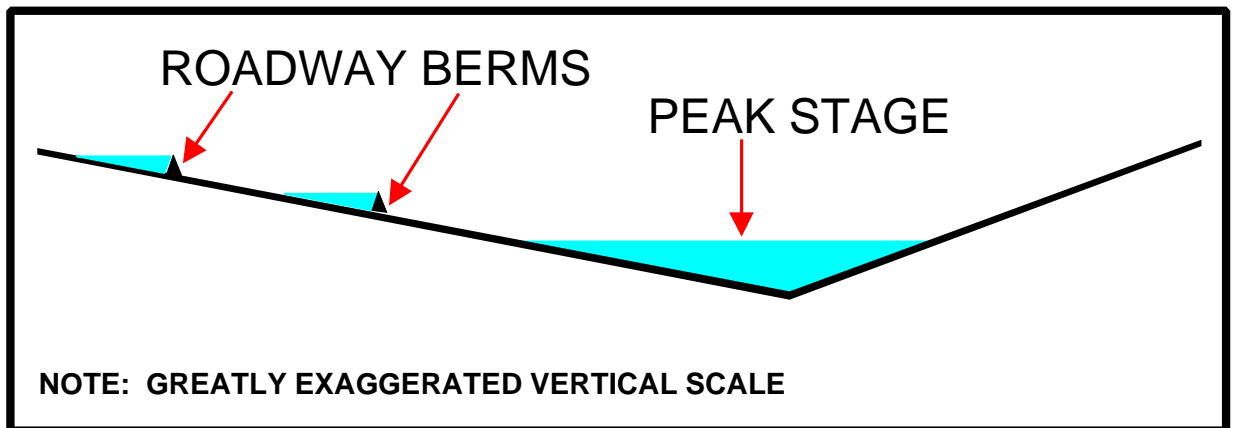
Recall the earlier brief discussion of a common adverse reaction to constructing berms across streets. This was answered, in part, by noting that stormwater berms have even less impact on vehicles than do the engineered and widely used speed humps.

A similar negative reaction is frequently expressed in response to the suggestion of intentionally storing stormwater on streets. Experiences in Skokie, Wilmette and elsewhere indicate that this initial objection may be offset by offering the following three points for consideration:



Note: Not to scale and great vertical exaggeration

**Figure 3-19.** Longitudinal profile of a street showing how a berm and flow regulator function as the outlet works of a temporary street storage facility (Source: Adapted from Loucks and Morgan, 1995).



**Figure 3-20.** Strategic placement of berms and flow regulators along a street facilitates use of the street's capacity to temporarily and in a controlled fashion store stormwater.

- Urban Streets often flood anyway, especially in flat topography typical of CSSs. That flooding is unintentional, uncontrolled and unexpected and can cause damage and excessive disruption of vehicular traffic as indicated by the upper portion of Figure 3-21.
- Stormwater “flooding” in the street storage system is controlled, that is, the peak stage and lateral extent are predetermined by the design of berms and flow regulators. The idea of street temporary controlled storage of stormwater is illustrated in the lower portion of Figure 3-21. The goal is to prevent damage to adjacent properties and not unnecessarily disrupt vehicular traffic.
- Controlled stormwater on streets is much preferred over uncontrolled combined sewage in basements.

Shown in Figure 3-22 are photographs of actual street storage in Skokie and Wilmette. Note that the ponding is shallow, does not prevent vehicular movement, and is contained within the public right-of-way.

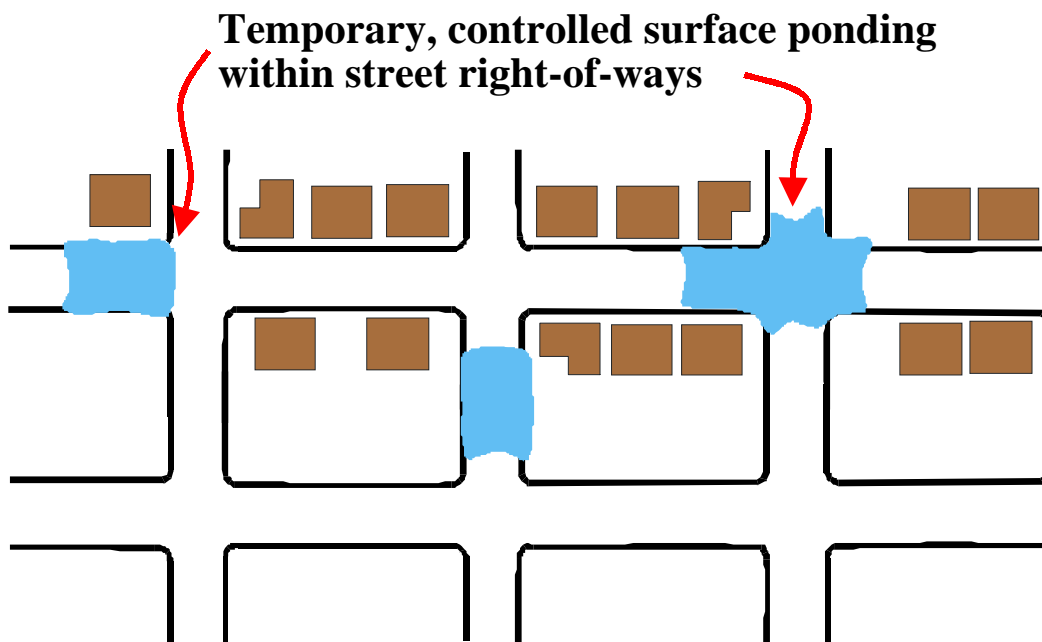
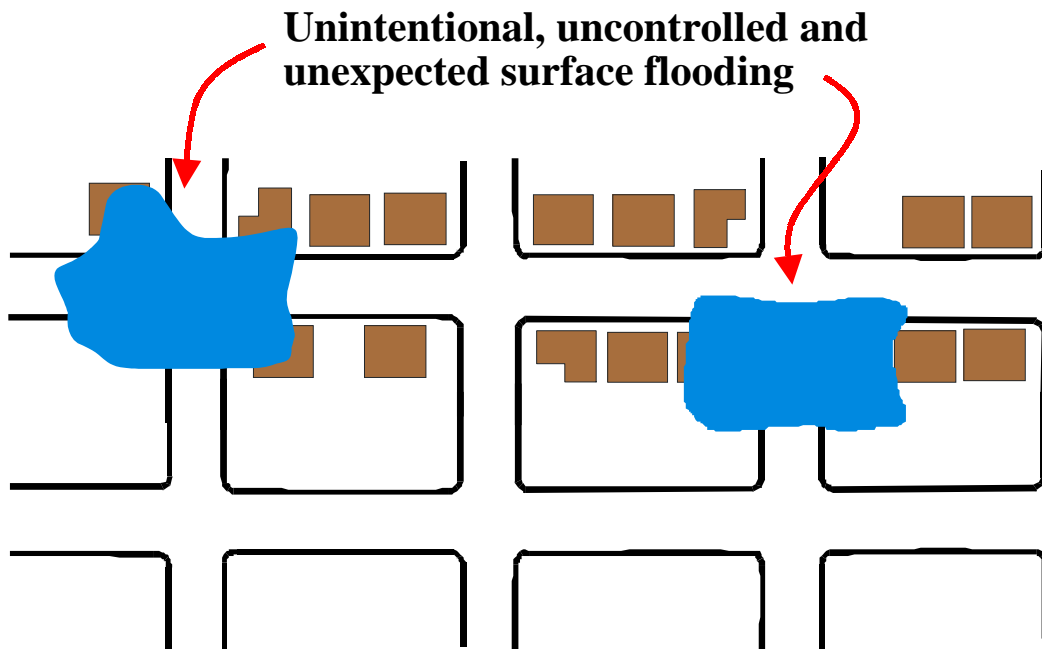
### ***Subsurface Storage***

Subsurface storage facilities are expensive, but sometimes necessary, components of a street storage system. They are used for temporary storage of stormwater beneath those streets and parking lots where the required surface storage would cause damage.

Subsurface storage is used only where absolutely needed because of the typical high cost per unit volume of storage. Accordingly, street storage systems will typically have very few subsurface storage facilities relative to on-street and other surface facilities. Skokie’s 8.6 square mile street storage system, for example, contains only 83 subsurface storage facilities compared to 871 berms and 2,900 flow regulators.

Figure 3-23 illustrates the function of subsurface storage. The facility lies within the public right-of-way and is positioned above the combined sewer. Its outlet is controlled by a flow regulator. Stormwater, not combined sewage, is temporarily stored in the facility.

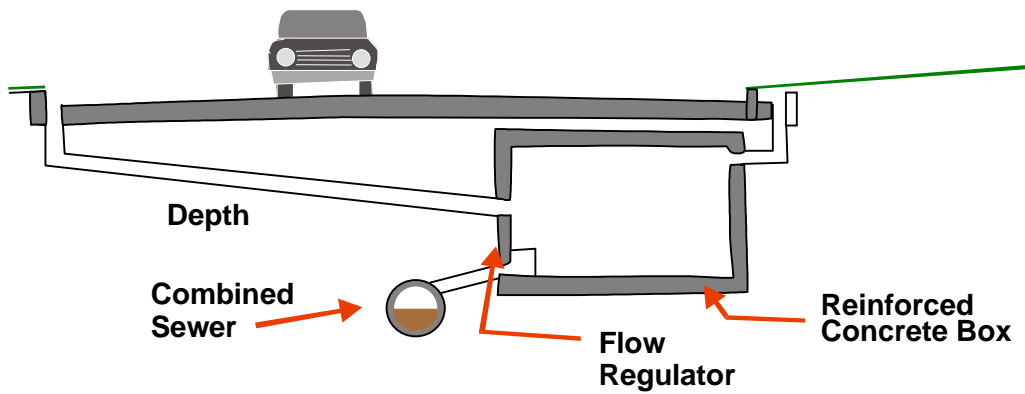
Actual subsurface storage facilities range from simple to complex configurations depending on the volume of storage required and site constraints. Some facilities are simply oversized lengths of storm sewer while others are large rectangular structures extending the length of a block and the width of the street. An example of the latter is illustrated in Figure 3-24. Shown is the construction of a subsurface storage facility composed of precast, reinforced concrete sections.



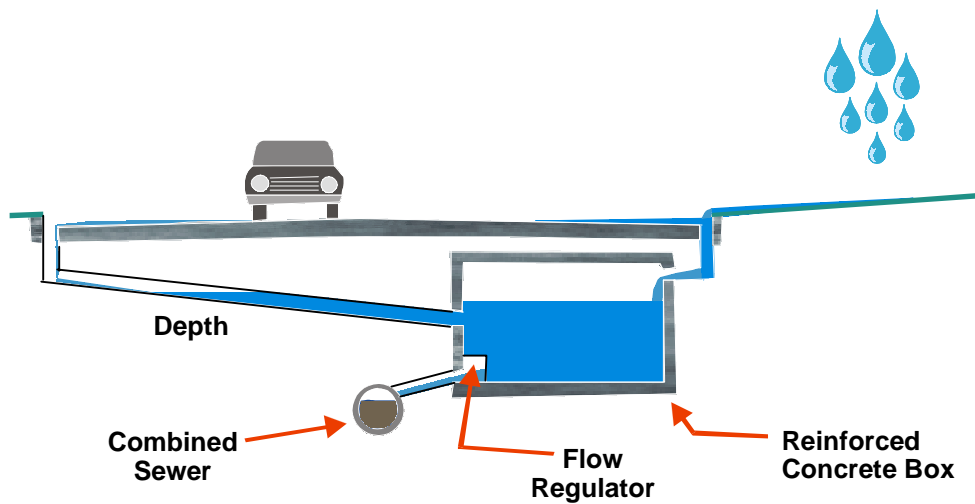
**Figure 3-21.** The street storage approach uses temporary, controlled ponding of stormwater in contrast with the common unintentional, uncontrolled and unexpected ponding resulting in damage and vehicular interference.



**Figure 3-22.** Actual street ponding in Skokie (top) and Wilmette (bottom).



*Dry Weather*



*Wet Weather*

**Figure 3-23.** Subsurface storage facilities are positioned within the right of way, above the combined sewer and temporarily stored stormwater, not combined sewage.



**Figure 3-24.** Subsurface storage facilities range from simple oversized lengths of storm sewer to, as shown here, large structures assembled from precast reinforced concrete sections.

## **Apply Screening Criteria to Determine Likely Applicability of A Street Storage System**

Refer to the section in Chapter 10 titled “Criteria for Screening the Applicability of Street Storage.” The screening criteria are based largely on ideas and information presented in this report, that is, the criteria reflects experience with the successful implementation of street storage systems. Included in the previously noted section of Chapter 10 are an explanation of the purpose of the screening criteria, comments about the qualifications of evaluators, reference to the actual criteria which are presented in Appendix B, suggestions for interpreting the information.

## **Select an Initial Pilot or Implementation Area Within the Combined Sewer System**

### ***Need for Phased Implementation***

Traditional public works projects, such as streets and highways, wastewater collection and treatment, and water supply treatment and distribution, are often implemented in a phased manner. Budgetary constraints are usually the reason for prioritization and phasing. That is, there is a need to spread capital costs over a period of years so that they match revenues.

Phasing means prioritization. If costs are the principal reason for phasing, then a phased public works project begins with the most cost-effective component. However, other factors can establish priorities including physical constraints, regulatory compliance, and political considerations.

When non-traditional approaches, such as street storage, are an integral part of a public works project, another important reason arises for phasing. That reason is the need to be cautious as the new technology is gradually conceptualized, planned, designed, tested, refined, understood, and accepted. Phased implementation was heavily used in the Skokie street storage project because it is the first large scale application of the street storage system in the U.S.

The key to effective phasing is selection of the first or pilot implementation area. The purpose of this section of the chapter is to offer suggestions, based on the Skokie, Wilmette and other experiences, on factors to consider in selecting the physical area for the first phase of a street storage project and then prioritizing subsequent phases.

### ***Prioritization Factors***

Many factors could be weighed in selecting an initial implementation area and prioritizing subsequent areas. Factors to use and their relative weights will depend on a given community’s physical, regulatory, and socio-economic situation. In picking an initial implementation area or the next area in order of decreasing priority, consider

selecting an area that:

- Includes a complete drainage system or watershed. The analysis and design process requires, for any point in the system, consideration of all significant conveyance and storage components upstream of that point. The entire 1255 acre HSSD, one of three combined sewer districts in Skokie, was selected as the initial area. It is a CSS watershed that discharges to the interceptor sewer system of the MWRDGC. While selecting a head water portion of this sewer district would have been acceptable, choosing a middle or lower portion of the district would conflict with this factor.
- Best satisfies the screening criteria for street storage. These criteria are introduced in the preceding section of this chapter, elaborated on in Chapter 10, and attached as Appendix B.
- Has a high concentration of basement flooding or other problems. By using this approach, and assuming implementation proceeds through construction, the selected area is likely to be very cost effective. That is, the ratio of problems solved to dollars expended should be higher than if other areas with less concentrated problems are selected.
- Reflects stakeholder input. An advisory committee of stakeholders might be formed to help select the initial implementation area. Stakeholder groups to be represented on the advisory committee might include homeowners, business people, educators, environmentalists, and regulators. Technical and other support should be provided by the community possibly with the assistance of their engineering consultant. In Skokie, the HSSD was selected by the community and then a consulting engineering firm was retained (Donohue, 1982a, p. 11).
- Has characteristics typical of other areas. Skokie, for example, selected portions of four streets covering approximately ten blocks within the HSSD for testing of flow regulators. The referenced pilot study is discussed in detail later in this chapter. One requirement for the testing of flow regulators was that the selected areas have a number of inlets and catch basins per unit area approximating that of the HSSD. In addition, street cross sections and widths in the selected areas were to be representative of the HSSD (Donohue, 1984a, pp. 3-13, 3-14). As further suggested by this Skokie example, use of one or more small pilot study areas within the overall initial implementation area may be prudent.
- Offers cost or other advantages if quick action is taken. As an example of this opportunity factor, one of several candidate CSS drainage areas may be slated for near future street resurfacing. Given that street geometry is

critical to street storage, that CSS drainage area may be the logical place to begin implementation of street storage.

## **Establish Performance Criteria**

### ***Need for Performance Criteria: Analysis and Design***

Before a CSS can be diagnosed, that is, analyzed to determine the cause of problems, the desired performance must be defined. The desired performance serves as the benchmark against which the severity of CSS problems and the nature of their causes can be measured.

Likewise, the prescription of solutions to a CSS's problems, that is, planning and design, cannot be undertaken until the desired performance of the CSS is defined.

### ***Variation in Performance Criteria***

Presented in this section of the chapter are examples of performance criteria used in the Skokie and Wilmette and other street storage systems. While there are some commonalities, the presented performance criteria show significant variations. This is to be expected for the following three reasons:

1. The street storage technology is relatively new and, therefore, rapidly evolving. Something learned in one project, or one phase of a given project, may change the performance criteria for the next project, or next phase of a given project.
2. Special circumstances. For example, a community with many tree-lined streets is likely to include in their performance criteria provisions intended to protect that amenity.
3. Different level of service expectations. Some communities have higher expectations for the level of public services that they receive and are willing to pay for.

Performance criteria presented here are not necessarily recommended for other communities. Rather, they are offered as examples of what some communities have developed to be consistent with their familiarity with the street storage technology, their special circumstances and their level of service expectations. Each community

contemplating use of the street storage system should formulate their own performance criteria, possibly using the criteria presented here as a guideline.

### ***Skokie Performance Criteria***

Performance criteria for Skokie's street storage system were first formulated in 1982 as part of the preliminary engineering for the HSSD (Donohue, 1982a, p. 5-1). They were slightly modified as part of a refinement of the HSSD preliminary engineering (Donohue, 1984, pp. 5-1, 5-2), the preliminary engineering for the MSSD (Donohue, 1987b, pp. 6-1, 6-2) and the preliminary engineering for the Emerson and Lake Streets Sewer District (Donohue, 1987a, pp. 5-1, 5-2). These criteria changed relatively little during this five year preliminary engineering period. Therefore, the performance criteria for the Emerson and Lake Streets are presented here as being representative of the Skokie approach.

The explicitly documented Skokie performance criteria may be summarized as follows:

1. The street storage system should be designed for the 10-year recurrence interval storm.
2. Reduce surcharging of sewers to prevent sewage backup caused by overloading of the municipal sewer system. The preliminary design of the alternatives is developed with the concept of defining maximum stormwater runoff rate into the sewers while preventing damaging sewer surcharging.
3. Make utilization of available street ponding capacity without causing flood damage to adjacent private development. Berms are to be used to detain stormwater on upland streets.
4. Minimize ponding on state and county highways. Stormwater ponding is discouraged on such streets. In locations where street storage on nearby streets could increase ponding depth on or near state and county highways, roadway berms are to be used to prevent ponding on the state or county highways. Storage facilities or relief sewers are to be used in no-pond areas to accommodate stormwater in excess of sewer capacity.
5. Establish maximum permissible flood stage for each street on a block-by-block basis. This stage, referred to as the "critical" elevation, is the highest stage which can be tolerated on the block without incurring flood damage such as first floor flooding and the flow of surface water through windows into basements or into below grade garages. In most cases the sidewalk elevation at the lowest point in the block is the critical elevation.
6. Confine temporarily stored stormwater within the right-of-way during the 10-year recurrence interval design storm. Right-of-way typically extends from the back of the sidewalk on one side of the street to the back of the

sidewalk on the other side. Limit the maximum depth of ponding for the 10-year storm to the lesser of six inches at the street centerline or nine inches at the gutter invert.

7. TARP Phase I provides a discharge point that will carry the stormwater runoff from a 10-year recurrence interval storm.
8. A gravity operated stormwater system is preferred to a pumped system. Minimal use of electrical and mechanical controls and equipment is desirable. A simple gravity operated system reduces the likelihood of failure and minimizes future operation and maintenance costs.
9. Storage of excess runoff should be accomplished first in off-street areas, second on streets, and last in underground storage facilities. Park and private property may also be considered assuming proper arrangements can be made.
10. Downspouts from one and two family residences are assumed to be disconnected from the CSS and to discharge to the land surface or storm sewer system in all street storage areas and in all areas without street storage but having storm sewers and/or stormwater storage facilities. Industrial, commercial and multi-family buildings and any buildings with internal drainage systems are excluded from this assumption.

### ***Wilmette Performance Criteria***

The explicitly documented performance criteria for Wilmette's street storage system may be summarized as follows:

1. "Alleviate basement flooding for the 10-year frequency storm event" (Rust, November 1993, p. 1).
2. "Reduce private property flooding (outside of the Village right-of-way) for the 10-year frequency storm event" (Rust, 1993, p. 1).
3. "Limit inconvenience to residents in accessing their property during major rainfall events" (SEC Donohue, December 1992, p. 7).
4. Confine street storage to public right-of-way (SEC Donohue, June 1992, p. 6).
5. Limit ponding depths to a maximum of six inches on the crown of a street and a maximum 12 inches above the gutter invert. Allow no ponding on sidewalks (SEC Donohue, June 1992, p. 7).
6. Exclude designated streets or street segments from ponding. These

streets were selected based on high traffic volume and/or proximity to schools, places of business, and access to or from elderly housing or fire and police stations (SEC Donohue, June 1992, pp. 7-8).

7. Generally consider berms only on streets with flat longitudinal grades—0.5% or less (SEC Donohue, June 1992, p. 16).
8. “Limit inconvenience to the community during the construction process” (SEC Donohue, December, 1992, p. 7).
9. “Limit increases in hydraulic loading on the North Shore Channel” (SEC Donohue, December 1992, p. 7).
10. “Limit increases in pollutant loading on the North Shore Channel” (SEC Donohue, December 1992, p. 7).
11. Limit peak flow discharged to TARP to the negotiated rate for the 10-year design rainfall events (Morgan, 1999).

Although not documented in the available Wilmette reports (SEC Donohue, June 1992; SEC Donohue, December 1992; and Rust, November 1993) other important performance criteria, in addition to the preceding list, were apparently applied in Wilmette. These seem to include the previously presented Skokie performance criteria 8, 9 and 10.

### **Analyze Existing System Using Monitoring**

The suggested systematic analysis and design process for a street storage system should include, as shown in Figure 3-5, monitoring data. That data may already exist from previous studies, may be collected as part of a special monitoring effort, or be a combination of the two. Regardless of data origin, the data should be used in parallel with the previous described computer modeling. Ideally, iteration should occur between modeling and monitoring as suggested by the dashed two-way arrow in Figure 3-5. For example, monitoring data should be used to calibrate hydrologic-hydraulic models. Initial modeling results should be used to identify gaps in the monitoring program. See Walesh (1989, Chapter 10) for a detailed discussion of the interplay between modeling and monitoring. Both Skokie and Wilmette used monitoring during the analysis and preliminary engineering process. Their efforts are described in the following sections.

#### ***Skokie Monitoring***

This summary of the initial monitoring program is taken from Walesh and Schoeffmann (1984). The monitoring program was conducted in 1983 to:

- Better define the behavior of the existing CSS.

- Provide baseline information to evaluate the performance of the street storage system, which would eventually be implemented.
- Provide data for refinement of the ongoing computer modeling effort.

An overriding consideration was selection of equipment, training of Skokie personnel, and installation of equipment in such a fashion that it could be moved to other sewer districts, after one or more years of service in the HSSD.

A 41 unit monitoring system was installed. It consisted of three rainfall monitoring stations; nine sewer flow monitoring stations with bottle racks installed at all nine monitoring stations and continuous monitors installed in six of the stations; 20 street ponding monitoring stations composed of 15 stations equipped with bottle racks and five with specially designed recording devices; and 10 footing drain flow monitoring stations, three of which were located in the HSSD and seven in adjacent sewer districts.

Installation, startup and calibration of equipment was carried out from January through March, 1983. Training of the Village staff, which occurred in the February through April, 1983 period, included chart changing, battery replacement, calibration, parts replacement and recording procedures. The monitoring system was operated as a joint effort between Skokie and Donohue & Associates, its consulting engineering firm, until the end of October, 1983. Additional, selective monitoring was conducted in 1984 within and outside of the HSSD.

The monitoring program revealed that precipitation exhibits significant spatial variation across the HSSD with half of 16 monitored major storms exhibiting such a variation. Dry weather flow values were found to be similar to those assumed in preliminary analyses (which relied solely on computer modeling as described in subsequent sections of this chapter) but exhibited significant spatial variation which was subsequently included in the refined analyses. Foundation drain flows were determined to be about one-third of the values assumed in the preliminary analysis. Accordingly, foundation drain contributions were reduced from about 2,900 gallons per day per house to about 1000 gallons per day per house.

### ***Wilmette Monitoring***

Flow monitoring was performed primarily to obtain data for calibration of SWMM. SEC Donohue (December 1992, p. 8) describes the monitoring program as follows:

*Flow meters were installed at five locations in the... sewer system and operated from July 10, 1991 through September 9, 1991. Rainfall over the flow metering period was measured using a continuous recording rain gauge. Total*

*rainfall for the flow monitoring period was 5.3 inches, the largest storm event was 1.6 inches, and a number of smaller events were also recorded.*

A second purpose of the Wilmette monitoring program focused on system behavior along the west boundary of the CSS. There was concern that MWRDGC interceptors along this boundary might surcharge and impact the tributary portion of the CSS. No surcharging occurred during the monitoring period. However, this observation was qualified by the fact that no severe rainfalls occurred during the monitoring. This is an example of using monitoring to diagnose system behavior.

## **Analyze Existing System and Perform Preliminary Design Using Computer Models**

### ***A Complex System: Need for Computer Modeling***

A typical combined sewer system is complex with its many and varied sanitary, stormwater and other inflows and its tendency to surcharge. Overlay a rectilinear system of street storage and conveyance components and the complexity increases.

Because of the complexity of the existing and possibly modified CSS, computer modeling has proven to be a necessity. Hydrologic-hydraulic computer modeling was heavily used in the Skokie and Wilmette projects. Computer modeling has been used for both analysis and preliminary design, that is, diagnosis of problems and development and prescription of solutions.

The models used and the manner in which they were used has naturally evolved, given the approximately 15 year period during which analysis and design occurred in the Skokie and Wilmette projects. Much was learned during this period as indicated by the subsequent sections. Presented here are summaries of computer modeling approaches used at various stages of the Skokie and Wilmette projects. Hopefully, the ideas and information presented will be helpful to CSS communities contemplating the use of computer modeling and the street storage approach.

Assuming a discrete event, contrasted with a continuous computer model (Walesh, 1989, pp. 321-324) is to be used, a design storm or design storms must be selected as part of the modeling. This typically includes decisions on recurrence interval, duration, volume, and hyetograph shape. Sensitivity analyses should be part of the process of formulating the design storm or storms. Detailed discussion of design storms is beyond the scope of this manual.

For in-depth discussion of design storms, see Walesh (1989, pp. 98-99, 112-113, 129, 304) and ASCE-WEF (1992, pp. 69-78, 226). An example of a sensitivity analyses

used to determine the critical duration for a design storm is provided by Walesh (1989, pp. 361-363).

### ***Analysis and Preliminary Design for the HSSD in Skokie***

A three-phased approach was used in the modeling and the analysis and preliminary design of the HSSD. The following description of the approach is taken from Walesh and Schoeffmann (1984).

Phase I was a simple static condition analysis, done without computer modeling, to determine the effect of North Shore Channel flood stages on flooding in the HSSD. Phase II was the steady-state hydraulic analysis of the sewer system, using a computer modeling, to determine the capacity available for stormwater runoff. Phase III was the determination of the location and extent of street flooding which would occur for various recurrence interval storms and the location and size of supplemental surface storage and relief sewers. This, the last phase was heavily dependent on computer modeling of the dynamic hydrologic-hydraulic system.

#### **Phase I - Analysis of Static Conditions**

This analysis determined if flood levels on the North Shore Channel, the ultimate receiving water for the HSSD CSS, would cause basement flooding solely as a result of backwater. The analysis was motivated by the observation that surface and subsurface storage of stormwater in the HSSD could not resolve basement flooding that resulted solely from North Shore Channel backwater effects. The analysis was conducted to determine if there were portions of the HSSD in which flood control could not be achieved by a street storage system within the HSSD.

The procedure used in this analysis is illustrated in Figure 3-25. North Shore Channel flood levels were obtained from the Corps of Engineers (Stadler, 1982) and the MWRDGC (MSDGC, 1981). Elevations of inverts and crowns of sewers in the HSSD, which were determined from sewer atlas maps and field surveys, were used to estimate the elevations of basement floors. Basement floor elevations were then compared to the flood levels.

The analysis concluded that there are no significant areas in which basement flooding would result solely from backwater of the North Shore Channel. Therefore, flood control within the HSSD might be achieved by an in-HSSD street storage system.

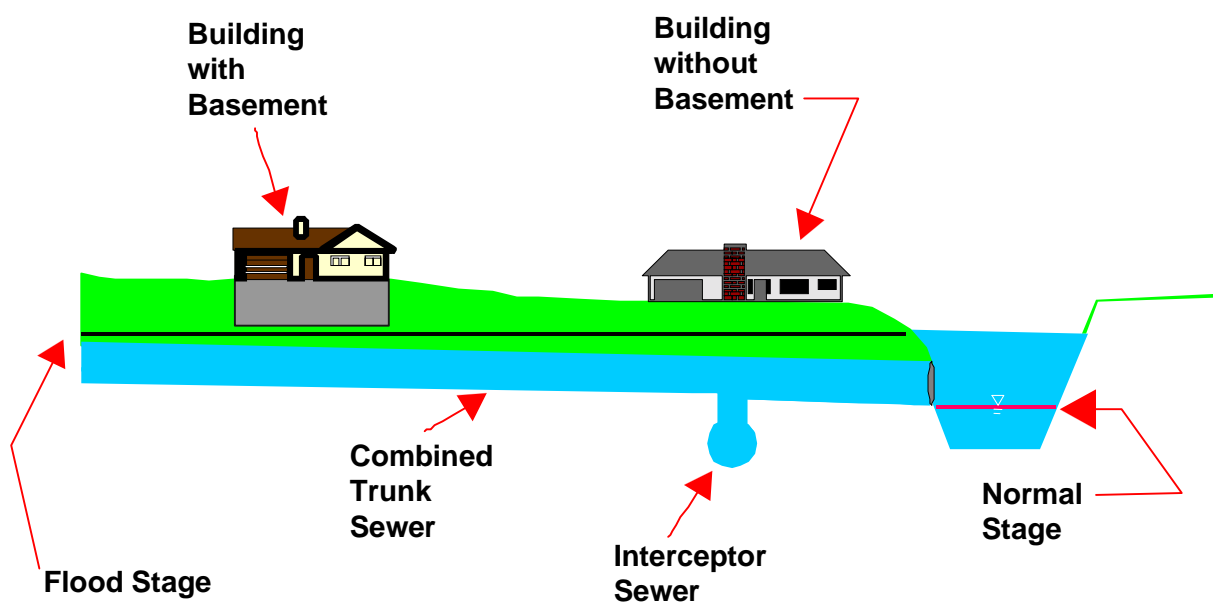
#### **Phase II - Analysis of Sewer Capacity**

The portion of the CSS capacity available for carrying stormwater runoff is a function of: the total hydraulic capacity of the system as determined by pipe size, slope, and

material; the quantity of sanitary flow, infiltration, and foundation drainage entering the system; and the level to which the sewer can surcharge without causing basement flooding or other damage. Capacity is also affected by the backwater effect of downstream sewers. The maximum allowable surcharge level was set at the crown of the sewers to avoid backup of combined sewage into basements.

For the sewer capacity analysis, flows representing foundation, sanitary and infiltration components were established based on a concurrent monitoring program. Roof drains were assumed to discharge to the land surface and no longer be directly connected to the CSS as a result of the Village's largely completed downspout disconnection program. The following flow components were used:

- Foundation flow: 5,000 gpd/acre or 0.0075 cfs per acre based primarily on monitoring.
- Sanitary and infiltration flow in residential areas: a total of 3,000 gpd/acre or 0.0047 cfs/acre for the western 90 percent of the HSSD and 6,000 gpd/acre or 0.0093 cfs/acre were used for the remainder of the HSSD based on monitoring.
- Sanitary and infiltration flow in industrial areas comprising the eastern approximately 10 percent of the HSSD: 11,000 gpd/acre or 0.017 cfs/acre based on monitoring.



**Figure 3-25.** Phase I, a simple static condition analysis, was used to determine if high stages on the North Shore Channel caused basement flooding in the HSSD.

The intent of the analysis was to determine the maximum rate at which stormwater runoff could be released into the CSS without exceeding the established surcharge level. The analysis is analogous to establishing the maximum allowable release rate from a conventional stormwater storage facility based on the capacity of downstream conveyance works.

The sewer capacity analysis was carried out using the computer program System Analysis Model (SAM), which permitted simulation of the entire HSSD and provided the computational means of accounting for system surcharges and hydraulic grade lines for each trunk and branch sewer (CH2M Hill, 1980). Refer to Figure 3-26 for an overview of the computer modeling procedure. The dry weather module of SAM was used to develop and input flows to the sewer system and the transport module was used to combine and route the flows through the sewer system. The HSSD was represented in the model as 101 subbasins, having an average area of 12 acres, and 161 sewer segments, having an average length of 300 feet.

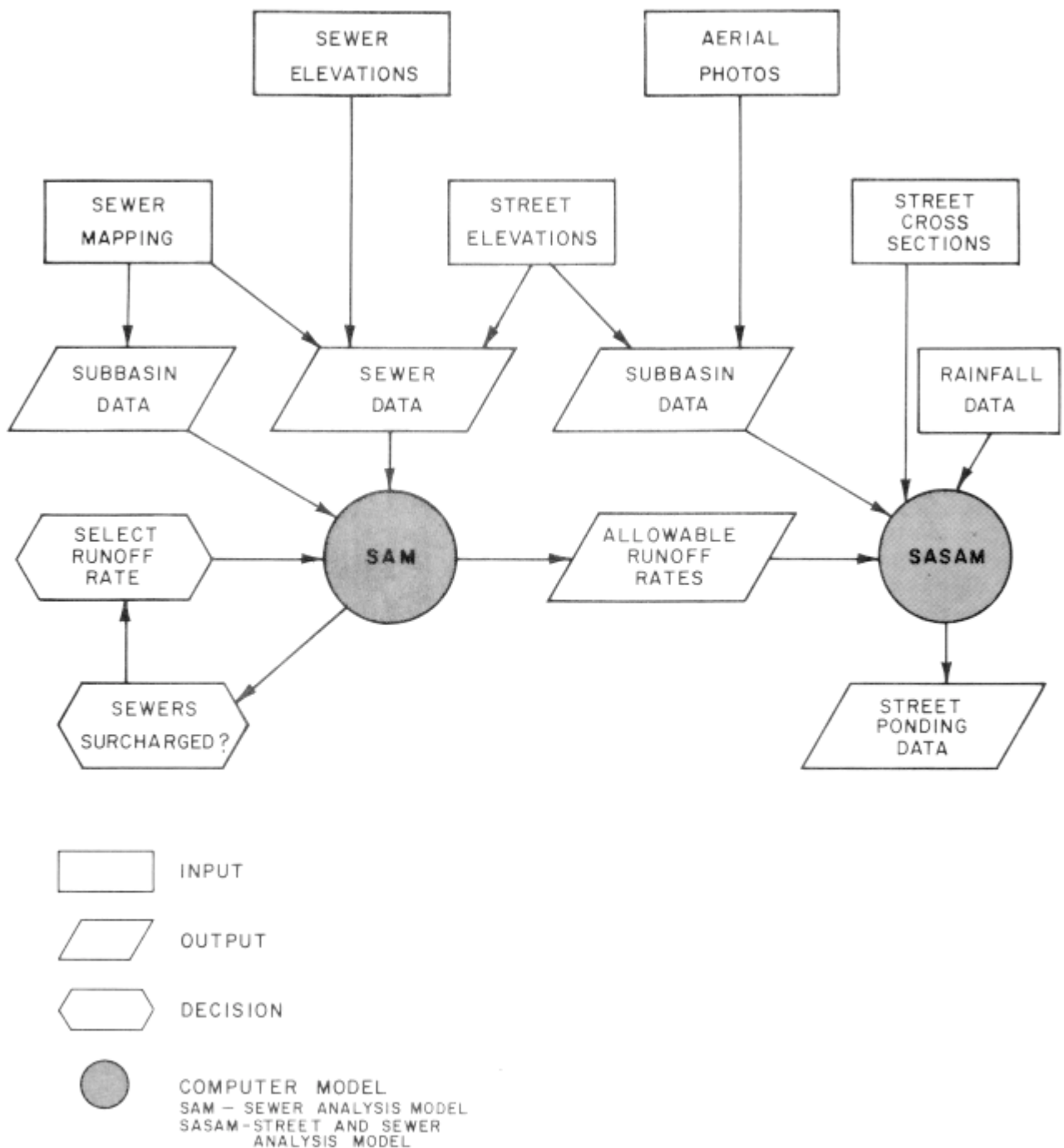
Foundation, sanitary and infiltration flows were input to the CSS. Increasing stormwater runoff rates were then progressively added to the sewer system on a subbasin by subbasin basis until the hydraulic grade line in the sewer met the established allowable surcharge level.

The allowable runoff rates represent design conditions, that is, the maximum rate at which stormwater can be released into the CSS without causing sewer surcharge and basement flooding. For this no-surcharge condition, the maximum allowable stormwater runoff rate ranged from 0.1 to 0.2 cfs per acre.

The resulting allowable stormwater runoff rates are extremely low. These unit area rates are equivalent to the runoff from an impervious surface that would be generated by a continuous rainfall intensity of only 0.1 inches per hour. Stated differently, the computer modeling diagnosis revealed that the HSSD combined sewers had very little capacity available for conveying stormwater runoff when allowance was made for sanitary sewage, foundation flow and infiltration.

### **Phase III - Preliminary Design of Street Storage**

This analysis determined the street ponding which would occur as a result of regulating the rate at which stormwater runoff could enter the CSS. More specifically, this analysis determined the location, depth, lateral extent, and duration of street ponding subject to the allowable stormwater release rate and other constraints as described below.



**Figure 3-26.** Computer model used for analysis and preliminary design in the Skokie HSSD (Source: Donohue, 1982a, p. 45).

A computer program, Street and Sewer Analysis Model (SASAM) was used for the analysis. Refer again to Figure 3-26. Note the relationship between SASAM and SAM. SASAM accepted historic or design rainfall hyetographs and computed runoff hydrographs as a function of subbasin area, time of concentration, and type of land cover using the British Road Research Laboratory Method (Stall, 1972). Flow in streets and on adjacent parkways was routed using the Manning equation plus conservation of mass to account for the conveyance capability of any given street section. Stormwater which ponded on street surfaces and adjacent parkways and lawn was accounted for by a reservoir routing procedure. Release of flow from the street surface to the sewer system was set at the maximum allowable release rates which could be handled by the sewer system as determined by Phase II. Examples of stage hydrographs produced by SASAM are presented in Figure 3-27.

The HSSD was partitioned into 278 subbasins having an average size of 2.4 acres for the Phase III analysis. Drainage area, percent directly connected impervious area, and time of concentration were determined for each subbasin. The street system was represented on a block-by-block basis requiring the use of 278 street segments. Representative street cross-sections, some of which are shown in Figure 3-15, were surveyed. Cross-sections extended from the street face of buildings on one side of the street to the street face of buildings on the opposite side and varied significantly.

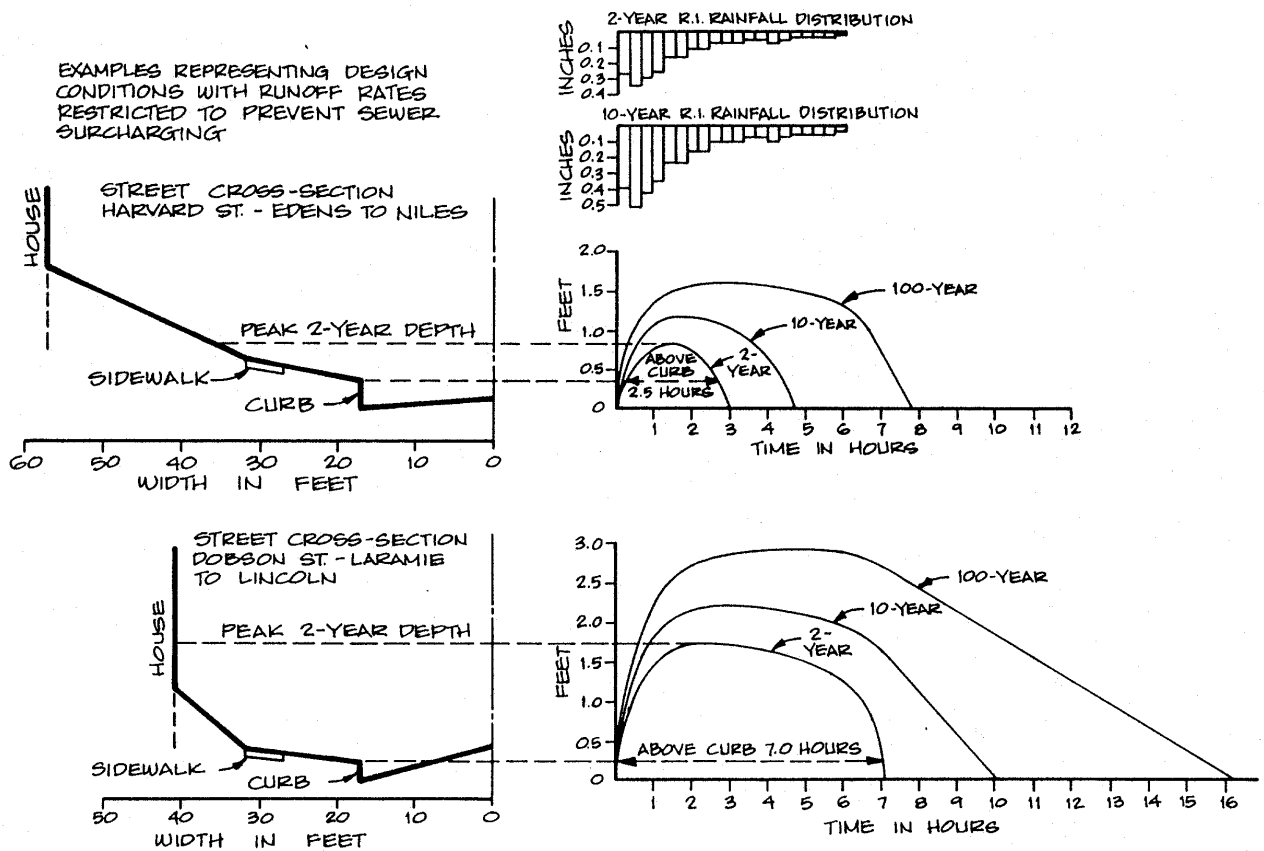
The first quartile storm distribution developed on the basis of historic rainfall data in the Chicago area was used in the analysis (Illinois State Water Survey, 1976). Sensitivity analyses using storm durations ranging from 30 minutes to 12 hours indicated that a six hour duration was most critical.

The lowest sidewalk elevation in each block was selected as the critical elevation for the block. The critical elevation is the maximum allowable ponding elevation under design storm conditions.

The modeling process moved on a block-by-block basis in the downstream direction. Excess water from each street was transferred to one or more adjacent downstream streets. In this manner, ponding was maximized for each block. Use of street surface berms was assumed for achieving stage control. Subsurface storage tanks were strategically placed to store excess stormwater from groups of streets having insufficient ponding capacity.

## **Results**

Largely as a result of the preceding three phased analysis and preliminary design process, the engineer recommended moving ahead with a street storage system throughout the HSSD. Skokie accepted the recommendation and implementation of street storage approach eventually encompassed the entire 8.6 square mile community.



**Figure 3-27.** Depth and duration of street ponding as a function of recurrence interval (Source: Welsh and Shoeffmann, 1984).

The three phased analysis and preliminary design approach developed for the HSSD was subsequently used, with refinements, on the other two districts comprising Skokie. Preliminary engineering was completed for both the MSSD and the ELSSD in 1987 (Donohue, May 1987a; Donohue, May 1987b). Thus, the substantial investment in developing the computer modeling-based analysis and preliminary design methodology for the HSSD yielded returns, not only on that district but also on the other two. As described in the next section, some of the modeling approach developed for Skokie was used in Wilmette.

### ***Analysis and Preliminary Design in Wilmette***

The USEPA Stormwater Management Model (SWMM) (Huber and Dickinson, 1992) was modified for analysis and preliminary design of the Wilmette street storage system (Loucks and Morgan, 1995). The modeling approach consisted of:

- Hydrologic simulation using the SWMM RUNOFF module.
- Street storage simulation using the SWMM EXTRAN module.
- Sewer system simulation using the SWMM EXTRAN module.

The EXTRAN model of the Wilmette street storage system is a surface network of storage junctions and berm overflows connected to a subsurface combined and relief sewer system.

### **Modification of the Stormwater Management Model**

Street storage simulator required three innovations, including two modifications. As explained by Loucks and Morgan (1995):

*Three innovations were required in the development of the street storage model. First, the EXTRAN code was modified to accept input of stage-storage relations for storage junctions and to generate descriptive storage junction output summaries of storage junction levels and outflow. Second, it was determined that the standard EXTRAN orifice formulation did not adequately represent field conditions for flow through a catch basin restrictor. An alternate to the equivalent pipe formulation was developed for use in the EXTRAN model. Third, the EXTRAN weir code was used to model flow overtopping of the berms into adjacent street storage sites.*

Each of the three SWMM innovations are now explained. This somewhat detailed explanation is provided primarily because SWMM is widely used in modeling urban wet weather conditions. Accordingly, communities contemplating a street storage system may also be thinking of using SWMM.

In the standard use of EXTRAN, storage junction data are input in the form of a depth and surface area relationships. Such a relationship is difficult to develop directly from street storage sites. This problem was resolved as follows (Loucks and Morgan, 1995):

*Available street storage volumes are from street cross-sections using the end area method. Software is available to compute street storage at depth intervals of 0.1 feet. The EXTRAN code was modified to accept stage versus storage volume input and to print an enhanced summary of storage junction results. The summary provides the maximum depth, storage and discharge for each storage site and identifies whether an overflow from the junction occurred.*

The software referred to in the preceding quote is SASAM, the previously described computer model used in the Skokie modeling. It was used to develop stage-storage relationships in the Wilmette project.

EXTRAN uses an equivalent pipe to represent an orifice. This representation differed greatly from the manner in which flow regulators were to be installed in Wilmette catch basins. For example, inherent in EXTRAN is the assumption that the water depth in the upstream junction exceeds the orifice diameter and that upstream and downstream junction elevations are about the same. This differs markedly from the expected Wilmette flow regulator installations, as shown in Figure 3-19, where the flow regulators are 1.5 to 4.5 feet below street grade and the receiving combined sewer is three to nine feet below the flow regulators. EXTRAN provided no way to position an orifice well below the storage junction invert. As explained by Loucks and Morgan (1995), the complication was resolved as follows:

*Laboratory tests by Spring (1983) demonstrated that a PVC tee-restrictor in a catch basin behaves as a classical orifice for a wide range of heads. The flow for a particular orifice area and head is given by formula  $Q=C_d a(2gh)^{1/2}$ , where  $g$  is acceleration due to gravity and  $C_d$  is a discharge coefficient found to be 0.60 to 0.65. In the context of the EXTRAN model, this formula is much better suited to the EXTRAN weir code rather than an equivalent pipe representation. The EXTRAN weir code was modified to accept a new type of weir representing a catch basin restrictor. Data inputs are the orifice diameter, the depth of the orifice below the ground, and the discharge coefficient. This approach is superior as long as there is no downstream submergence. Even then it is still more accurate than the equivalent pipe, but not as stable computationally.*

Berm overflow and flow exchange between adjacent street storage areas are important phenomena in the street storage system. All stormwater flow and volume must be accounted for. As explained by Loucks and Morgan (1995):

*Berm overflow is employed to fully utilize available storage and to convey stormwater to relief sewer locations from individual ponding areas, which may not have sufficient storage volume. Simulation of berm overflow has been implemented in the EXTRAN model using the standard transverse weir input.*

## **Application of the Model**

The previously described model was used for analysis, preliminary design, final design, and post-construction verification. More specifically (Loucks and Morgan, 1995):

*In the feasibility analysis, storage sites were grouped together using a single storage junction to represent ten or more ponding areas. During design and construction, the planning level models were refined to support and verify the design of street storage location, relief sewer configurations, relief sewer connections to existing combined sewers, and restrictor sizes. These models stretched the traditional data limits of EXTRAN. Current models representing the two completed phases feature over 250 pipes and 350 junctions including more than 100 storage junctions.*

The model was calibrated against precipitation and flow data for July 13 and July 30, 1992 storm events, each of which had recurrence intervals of about three months. Analyses of sensitivity of the system to design storm duration revealed that the six hour event "...produced the greatest amount of system overflow and the most prolonged time of widespread sewer surcharge." System analysis indicated that one-year frequency and larger storm events surcharge the CSS and cause basement and street flooding (Rust, November 1993, p. 4). This finding was consistent with Wilmette's historic basement and street flooding problems.

## **Results**

The engineer recommended implementing the street storage system in Wilmette as a result of the previously described computer modeling based analysis and design process. Wilmette accepted the recommendation and implementation of the street storage approach will eventually encompass the entire 2.0 square mile CSS.

## **Review Flow Regulator Availability and Performance**

### ***Essentiality of Flow Regulators***

Flow regulators, as explained earlier in this chapter, are an integral part of the street storage system. They must be properly sized to achieve the desired stage-discharge relationship at any given storage location.

Equally important is selection of the type of flow regulator for a particular application. Reason: relative to berms, subsurface tanks, relief sewers and other components, flow regulators are most prone to failure. The most common failure mechanism is partial or total plugging by debris carried in stormwater runoff. Plugging can, in turn, lead to excessive upstream storage and stage and, after a rainfall event, prevent the gravity drainage of stored stormwater. Therefore, the type of flow regulator selected must fit the environment within which it is installed.

### ***Skokie Flow Regulator Study***

A flow regulator testing program was carried out in the early stages of the Skokie street storage project. It had been recommended in the preliminary engineering study for the HSSD (Donohue, 1982a, p. 115). At that time, in the early 1980's, little was known about flow regulators. Flow regulators were viewed as likely pivotal components of the evolving Skokie street storage program, and, therefore, a special flow regulator study was warranted.

Presented here is a synopsis of the testing program based largely on Donohue (March 1984a). The first purpose of the synopsis is to sensitize potential users of flow regulators to flow regulator features so that informed decisions can be made. The second purpose of this synopsis is to provide information about specific flow regulators.

### **Purpose**

The overall purpose of the flow regulator study was an equitable and objective evaluation of flow regulators under field conditions likely to be encountered in a system-wide application of regulators in Skokie. Sometimes laudatory and occasionally conflicting claims of equipment manufacturers and suppliers pointed to the need for a comparative field test. Based on a literature search and personal contacts, such a test had apparently never been carried out.

More specifically, the purpose of the flow regulator study was to: determine the initial cost of commercially available flow regulators and devices specially fabricated by the Village and others; evaluate flow regulator installation, removal and adjustment requirements; and observe and evaluate the hydraulic and other performance characteristics of flow regulators under a variety of field conditions.

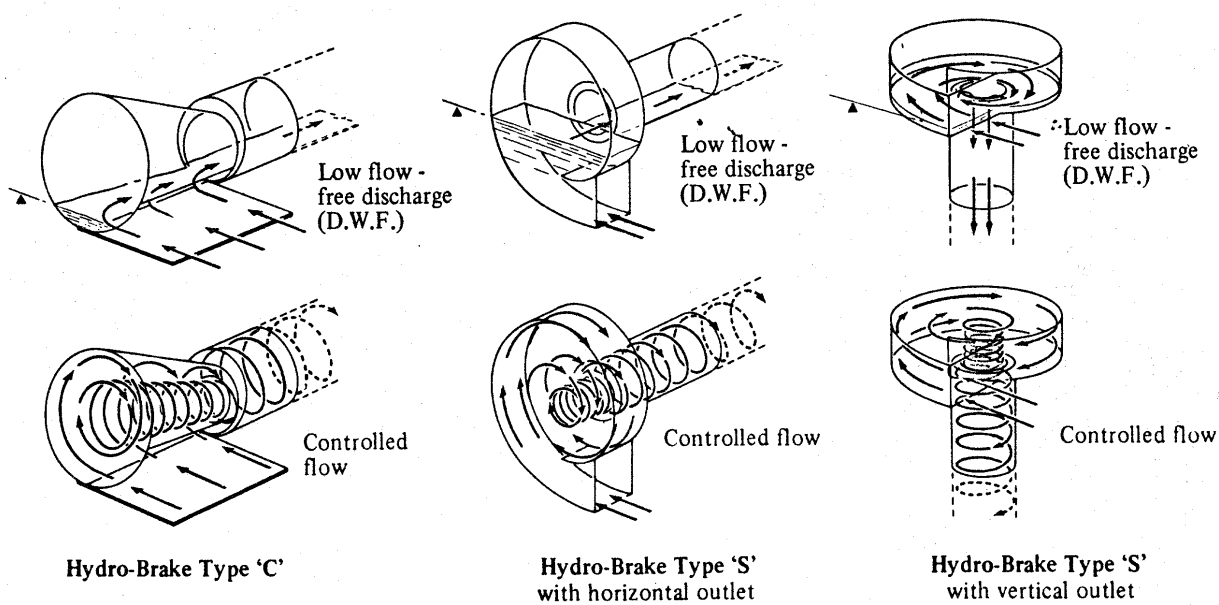
### **Literature Search and Interviews**

A literature survey and personal interviews identified the following five types of flow regulators potentially applicable to the HSSD:

1. The commercially available Hydro-Brake unit as illustrated in Figure 3-28. Flow enters the unit perpendicular to the outlet pipe, is turned through 90 degrees, and is discharged. The resulting turbulent flow pattern causes a

much higher energy loss than would occur through an orifice of similar diameter. Therefore, for a given head, the discharge through a Hydro-Brake was half or less than half that which would occur through an orifice having a cross-sectional area equal to the smallest free opening of the Hydro-Brake. That is, although the Hydro-Brake and the orifice would have similar ability to pass debris, the Hydro-Brake would reduce flows by one-half or more.

As noted by Pisano (1989), the Hydro-Brake is an example of a vortex flow throttling device. Vortex regulators were first developed in Denmark in the mid 1970's. They were used in Denmark and Sweden to mitigate basement flooding within CSSs.



**Figure 3-28.** Examples of Hydro-Brake flow regulators, available in the early 1980's, illustrating the basic operation of vortex type regulators (Source: Hydro Group, 1982).

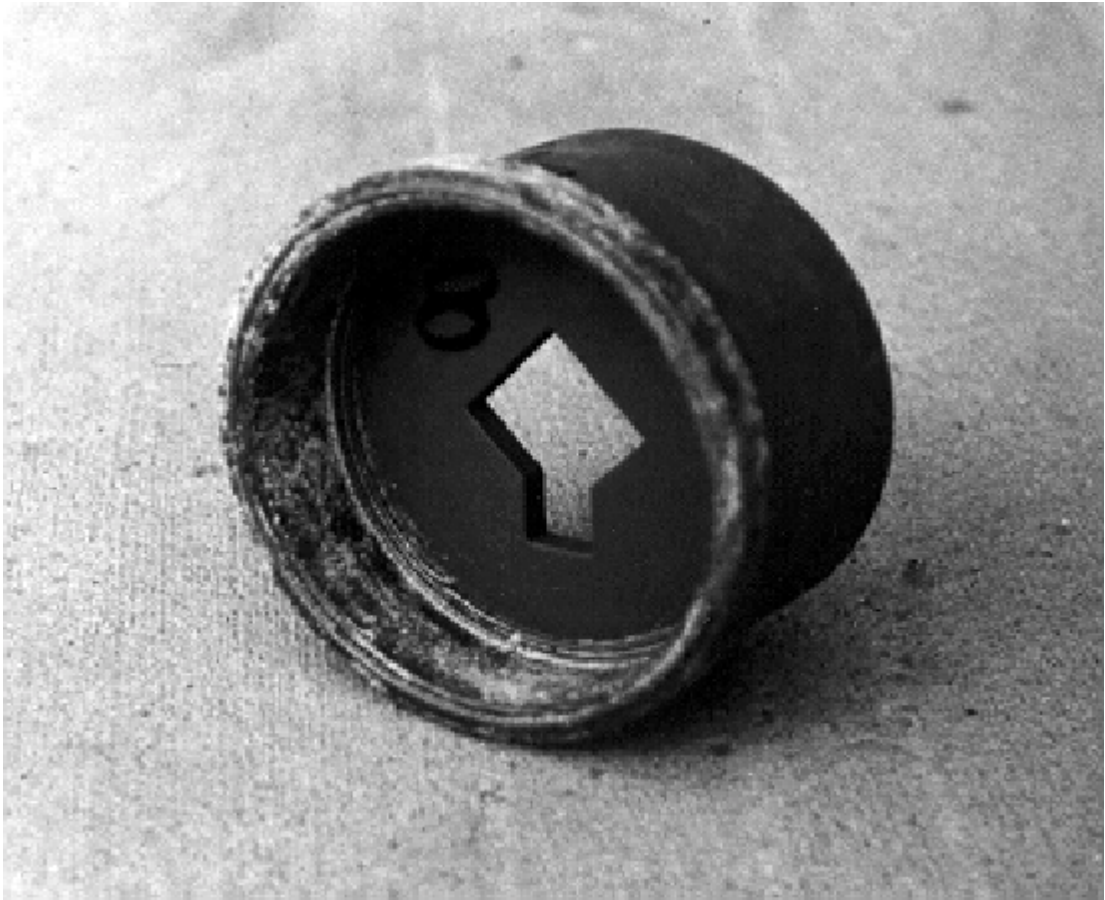
2. The commercially available Scepter units. A photograph of one is shown in Figure 3-29. The orifice is diamond shaped with a rectangular keyway at the bottom. The principal purpose of the keyway is to keep buoyant debris below the bottom of the diamond during dry periods. At the onset of a runoff event, the device is expected to function such that buoyant debris jammed against the keyway will rise, encounter the wider diamond portion of the orifice, and immediately flow through the regulator.
3. Specially fabricated solid cover with orifices. Figure 3-30 is a photograph of one of these devices. For a given head, a few small orifices reduce the flow significantly compared to the flow through a standard inlet grate with its many larger openings.
4. Horizontal orifice plate beneath the inlet grate as shown in the photographs in Figure 3-31. The single, small orifice helps to trap leaves, twigs and other debris carried by the stormwater before the material reaches the underlying orifice.
5. Hanging trap flow regulator, as illustrated in Figure 3-32. This device, which can be assembled from inexpensive, standard PVC units, features an orifice that is always submerged.

### **Design of the Field Study**

Portions of four streets, covering approximately ten lineal blocks on the west side of the HSSD, were selected for the field phase of the flow regulator study. Factors considered in selecting the test areas included: a variety of topographic features such as streets with uniform and non-uniform longitudinal slopes; a range in type of street cross-sections and street widths; an aerial density of inlets and catch basins similar to that of the entire HSSD; a mix of residential and commercial streets; and the presence of trees.

### **Equipment Acquisition and Installation**

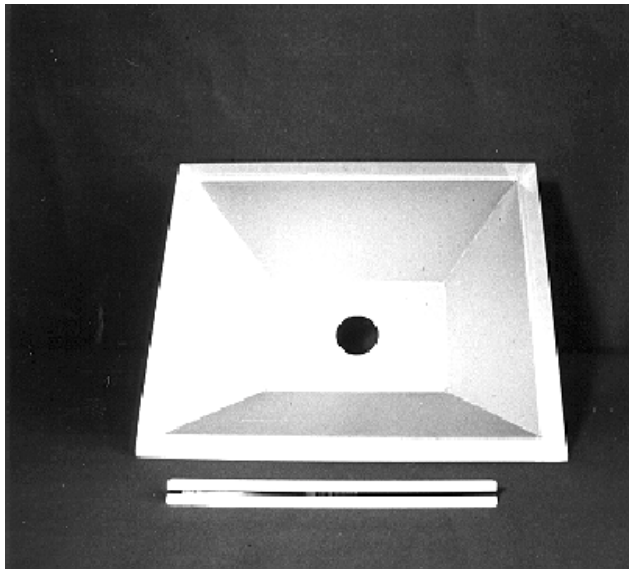
A total of 29 flow regulators were installed in the study area during the period of January through April 1983. The Hydro-Brake and Scepter units were installed in both catch basins and inlets. The hanging trap unit was applicable only to catch basins. The orifice in the inlet grate and the horizontal orifice plate beneath the grate were suited only to inlet installations.



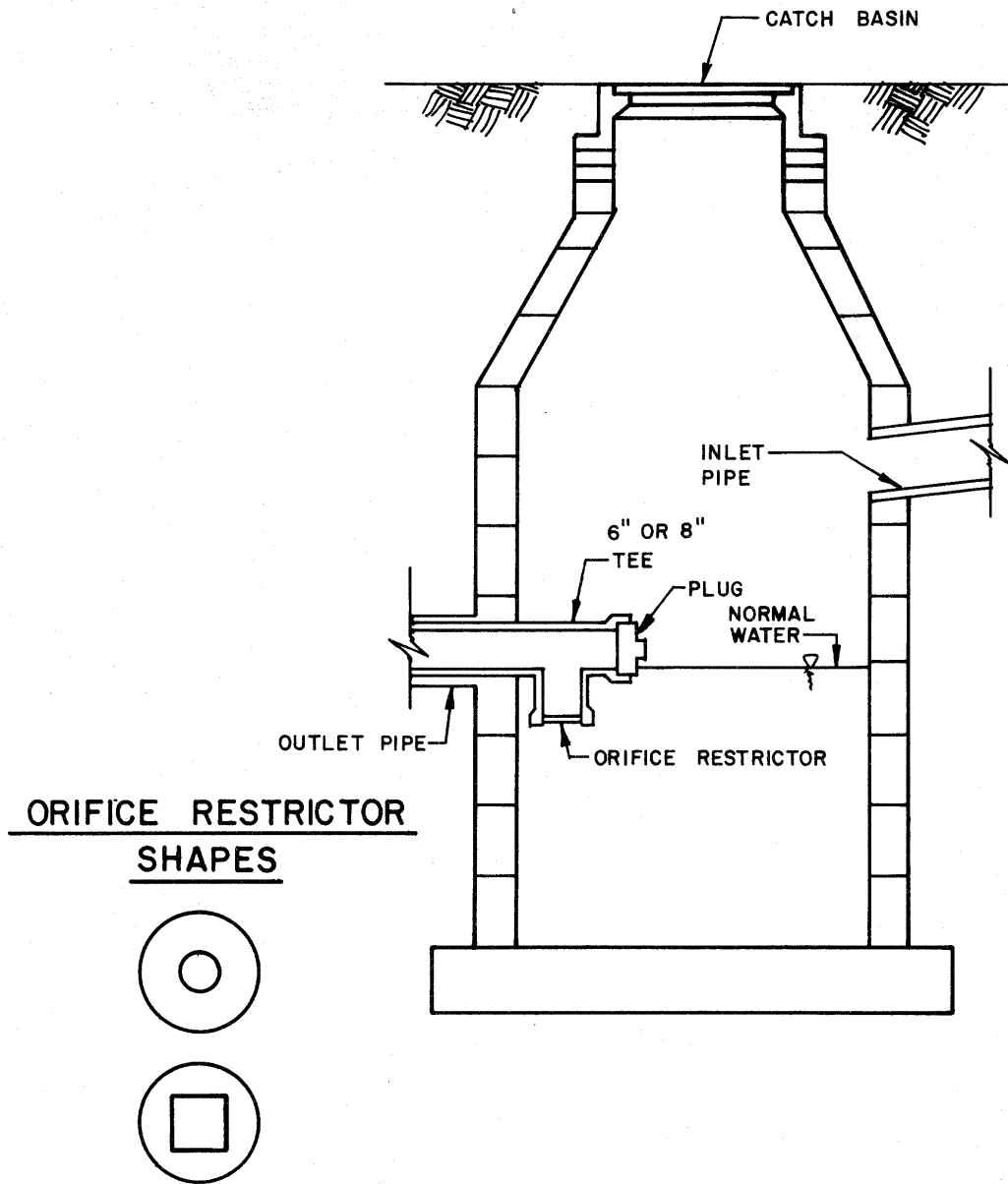
**Figure 3-29.** Photograph of Scepter flow regulator.



**Figure 3-30.** Photograph of solid cover with orifices.



**Figure 3-31.** Photographs of horizontal orifice plate flow regulator before and after installation.



**Figure 3-32.** Hanging trap flow regulator (Source: Donohue, 1982a).

## **Observation Procedures**

The system of 29 flow regulators was observed by Skokie and Donohue personnel during or immediately after a total of 15 rainfall-runoff events between March 18 and September 20, 1983. In addition, regulator performance was observed during intentional flooding tests conducted on October 18 and November 16, 1983. A photograph of the intentional street flooding is shown in Figure 3-33. The field observations of flow regulators focused on operation and maintenance factors such as the tendency of the regulators to plug with leaves and other debris and the ease of removing material from plugged regulators.

## **Rainfall**

The average intensity of 60 percent of the rainfall events occurring during the six month field tests exceeded 0.1 inches per hour which approximately corresponds to a unit runoff rate of about 0.1 cfs per acre, the rate above which flow regulators had to function as part of the HSSD street storage system to prevent damaging surcharging. Therefore, the majority of rainfall events, and all intentional flooding tests, simulated operational conditions.

## **Resistance to Plugging**

From a plugging perspective, flow regulators were much more resistant to plugging when placed in catch basins than inlets—the latter installations were 20 times more likely to plug than the former. There was no significant difference in the operation characteristics of Hydro-Brakes, Scepter units, and hanging traps placed in catch basins—they all performed very well.

Although there were significant differences in the anti-plugging performance of inlet installations of Hydro-Brakes, Scepter units, grate modifications and horizontal orifice plates, the difference was of little practical significance because the incidence of plugging was too high. That is, even a relatively low plugging frequency of inlet installation is unacceptable for the street storage system. Leaves appeared to be the principal cause of plugging of flow regulators. This dominance probably reflects the large supply of leaves relative to other materials.

## **Costs**

The cost of purchasing flow regulators varied widely. Cost ranges per unit in 1983 for units appropriate to Skokie inlet or catch basin installations were:



**Figure 3-33.** Streets were intentionally flooded to test the performance of flow regulators.

- Hydro-Brake: \$300 - \$800
- Scepter: \$100 - \$130
- Solid cover with orifice: \$10 - \$50
- Horizontal orifice plate beneath inlet grate: \$50 - \$150
- Hanging trap: \$25 - \$50

Given the good and similar operating characteristics of Hydro-Brakes, Scepter units, and hanging traps, the hanging traps were clearly preferable because of their very low costs.

### **Maintenance**

The ease with which debris can be removed from plugged flow regulators was difficult to quantify. The debris removal effort, listed in order of increasing difficulty, is approximately as follows: modified grate flow regulators; horizontal orifice plate positioned beneath the inlet grates; Hydro-Brake and Scepter flow regulators installed in inlets; and Hydro-Brakes, Scepter units, and hanging traps installed in catch basins.

#### **Conclusions for Skokie**

1. Flow regulators should be installed in catch basins, rather than inlets.
2. Hanging trap flow regulators should be used throughout the HSSD, except where the desired reduction and resulting orifice size is beyond the effective lower range of the hanging trap regulator, in which case Hydro-Brake flow regulators should be used.
3. A field-oriented flow regulator design process should be used to minimize costs.
4. The design and installation of flow regulators should be done in conjunction with other components of recommended street storage system including roadway berms, subsurface storage tanks, and relief sewers.

### **Complete Design of the Street Storage System**

The goal of final design is to produce a set of plans and specifications to be used by contractors for bidding and by the selected contractors for construction. Additional hydrologic-hydraulic modeling is needed for tasks such as final sizing of flow regulators and refinement of berm locations and heights. However, the final design process is typical of that which might be done for an urban street. An example of the kind of detail that results is shown in Figure 3-34.

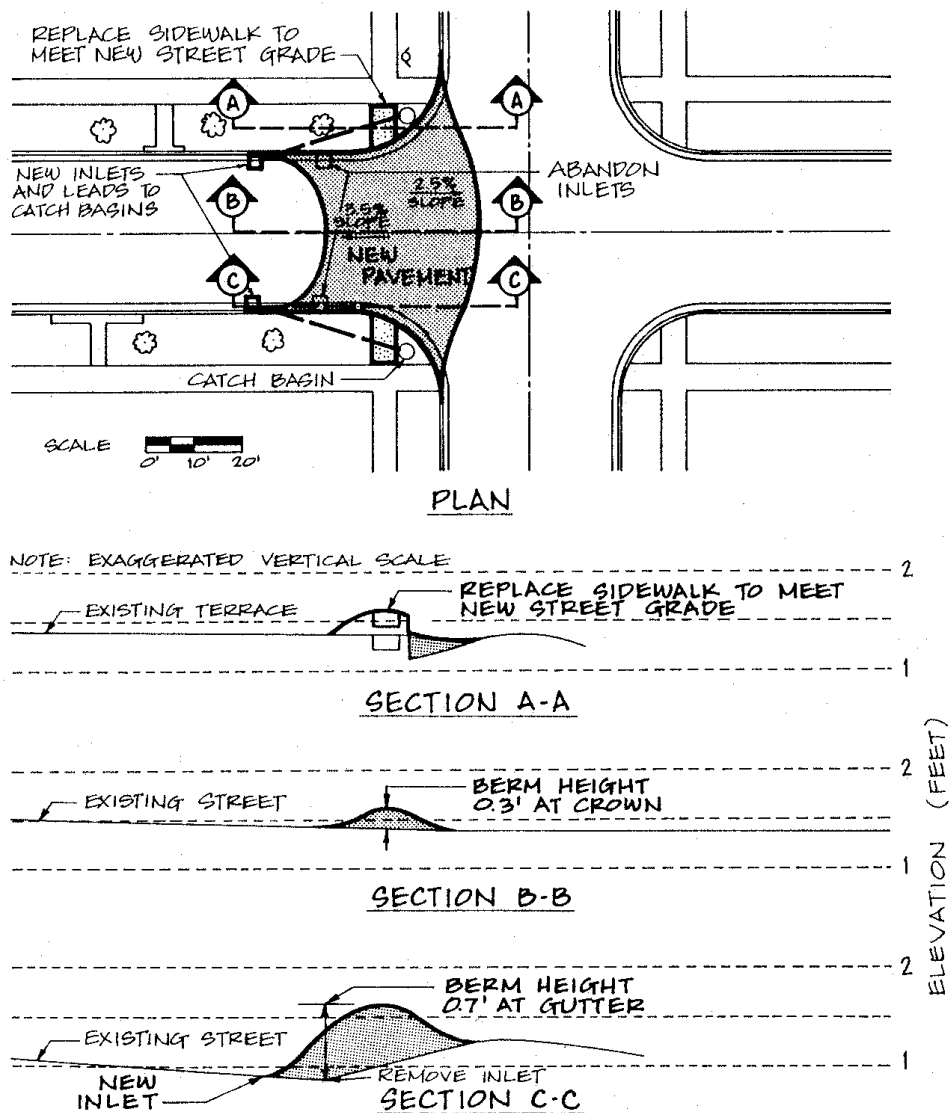


Figure 3-34. Typical street berm design in Skokie, IL (Source: Walesh, 1989, p. 401).

## **Construction**

Both Skokie and Wilmette are using a phased approach to construction. (For a discussion of the advisability of phased implementation and suggested prioritization

factors, refer to the earlier section of the chapter titled “Select an Initial Implementation Area Within the Combined Sewer System.”) Each community’s overall implementation schedule, with emphasis on construction, is summarized here.

### ***Skokie Construction***

Skokie implemented the physical aspects of its street storage system according to the following schedule:

- 1981: Initiate downspout disconnection
- 1983: Begin stakeholder involvement
- 1983: Test flow regulators in pilot areas
- 1983: Initiate base line monitoring
- 1983-1986: Construct HSSD
- 1988-1997: Construct MSSD
- 1989-1999: Construct ELSSD

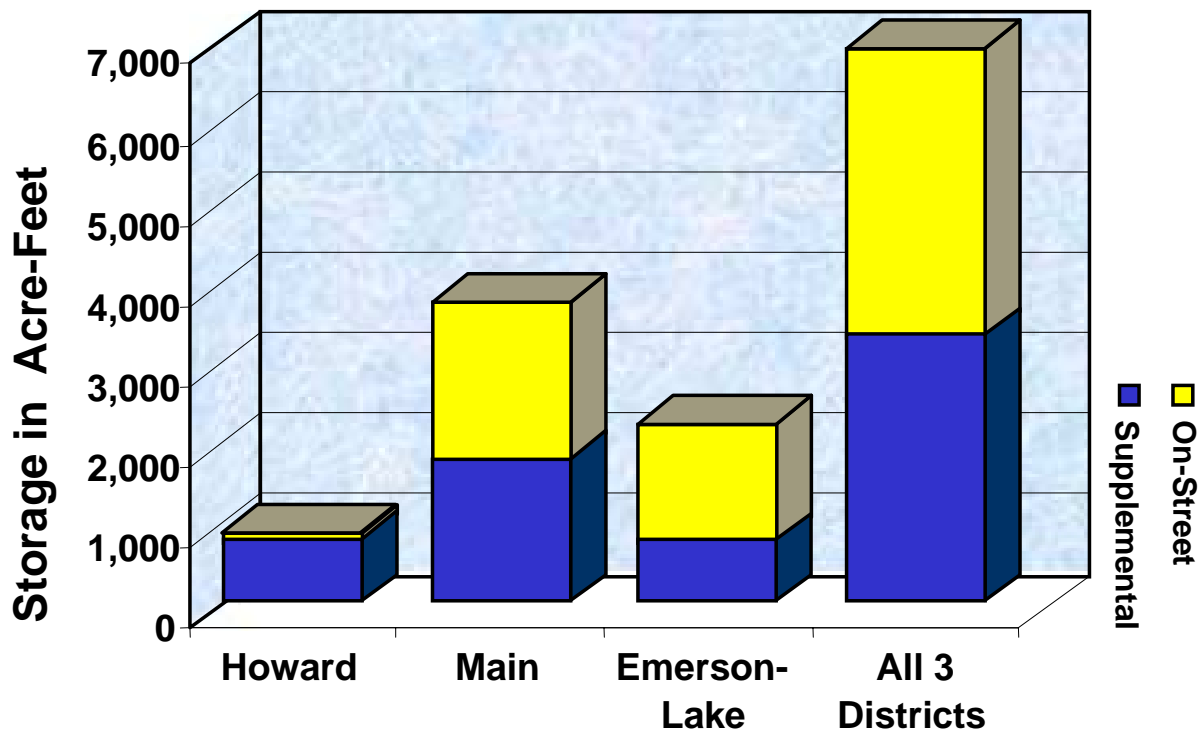
Table 3-3 summarizes the components of the Skokie street storage system. Note the heavy reliance on berm-flow regulator installations, which suggest, in turn, widespread use of temporary, controlled street ponding.

The relative importance of street storage versus other storage is shown in Figure 3-35. Overall, street storage accounts for half of the total stormwater storage capacity in Skokie, the other half being subsurface storage and off-street surface storage. Incidentally, in Wilmette essentially all of the storage is street storage because there are no subsurface or off-street storage facilities.

The preceding observations about the dominance of street storage in Skokie and Wilmette reinforce the discussion near the beginning of this chapter about the significant storage and conveyance capacity of street, especially in a CSS. With carefully engineered retrofitting, that storage and conveyance can be the basis for cost-effective solutions to flooding and perhaps other wet weather problems in CSSs.

**Table 3-3.** Components of the Skokie street storage system (Source: Carr, 1999).

<b>Component</b>	<b>Number</b>	<b>Length (Feet)</b>
<b>Flow Regulators</b>	<b>2,900</b>	<b>- - -</b>
<b>Berms</b>	<b>871</b>	<b>- - -</b>
<b>Off-Street Surface Storage</b>	<b>10</b>	<b>- - -</b>
<b>Subsurface Storage</b>	<b>83</b>	<b>- - -</b>
<b>Storm Sewer</b>	<b>- - -</b>	<b>64,000</b>
<b>Combined Sewer</b>	<b>- - -</b>	<b>29,000</b>



**Figure 3-35.** Street storage accounts for half of the total stormwater storage in Skokie (Source: Carr, 1999).

## ***Wilmette Construction***

A five-phased construction program is underway in Wilmette. Three phases are completed and two are planned. Two major considerations determined the priorities. The first was functional dependence. For example, downstream relief sewers were constructed before upstream relief sewers. The second of the two key prioritization factors was cost effectiveness. That is, higher priority was given to areas with the most severe problems. The five phases, with their actual construction costs (Phases 1, 2 and 3) and projected construction costs (Phases 4 and 5) are described below.

### **Phase 1: Greenleaf Avenue Relief Sewer**

Included installation of approximately 6300 lineal feet of relief sewer (48" - 96") in Greenleaf Avenue, connection to the deep tunnel, emergency overflow to the North Shore Channel, and 165 berms and associated catch basins and flow regulators.

Cost: \$10,358,000

### **Phase 2: Eastside Relief Sewer**

Consisted of the continuation of relief sewers from Greenleaf Avenue, along 9th Street and Forest Avenue to 15th Street. This tunneled sewer project consisted of approximately 5600 lineal feet of 72", 54", and 48" diameter sewers. This phase also included the construction of 50 berms and related catch basins and flow regulators.

Cost: \$4,586,000

Cumulative Cost: \$14,944,000

### **Phase 3: Eastside Relief Sewer**

Included both construction of relief sewer to the south from Greenleaf Avenue and a storm sewer system (including an outfall to the North Shore Channel) in the Maple/Dupee portion of the Village. This Phase included the construction of 37 berms and related catch basins and flow regulators.

Cost: \$8,425,000

Cumulative Cost: \$23,369,000

### **Phase 4: Eastside Lateral Relief Sewer**

Will consist of the construction of relief sewers in 9th Street from Forest Avenue to Chestnut; Ashland Avenue from 9th Street to 8th Street; 8th Street from Ashland

Avenue to Chestnut Avenue; 12th Street from Forest Avenue to Ashland Avenue with one block stubs on Elmwood, Greenwood, and Ashland; 17th Street from Lake Avenue to Forest; and 17th Street from Forest Avenue to Elmwood Avenue. These sewers will range in size from 18" to 36" in diameter.

Cost: \$4,500,000

Cumulative Cost: \$27,869,000

### **Phase 5: Eastside Lateral Relief Sewer**

Will consist of relief sewers in 6th Street from Greenleaf Avenue to Elmwood Avenue; Forest Avenue from 6th Street to Michigan Avenue; Elmwood Avenue from Sheridan Road to Michigan Avenue; and Washington Avenue from Prairie to Green Bay Road. A portion of the Phase 5 sewers will be constructed in Green Bay Road as part of the Green Bay Road resurfacing project. This phase will also include storm sewers at various locations across the Village. These sewers are proposed to pick up primarily surface drainage from low lying areas.

Cost: \$7,300,000

Cumulative Cost: \$35,169,000

In summary, as of early 1999, the constructed three phases of the street storage system in Wilmette's two square mile CSS consist of:

- 252 berms - catch basins - regulator installations. Over 98% of the intended 717,540 ft<sup>3</sup> (16.5 acre-feet) of street storage has already been achieved.
- Over 11,900 lineal feet of tunneled or conventionally constructed relief sewer.
- Incidental storm sewers.

The \$23,369,000 total cost of the three completed phases consists of \$18,946,000 or 81.1%, for relief sewers and \$4,423,000 or 18.9%, for berms and associated catch basins and flow regulators.

Because the CSS is essentially one system, all phases must be completed to achieve the intended degree of flood control. The last two phases of the five phased program are not yet constructed.

wp/epastch3

## **CHAPTER 4**

### **OTHER EXAMPLES OF STREET STORAGE SYSTEMS**

#### **Purpose**

Using the well established and on-going Skokie and Wilmette, IL project; the previous chapter presents a proven and practical street storage system concept through construction and operation and maintenance process. Provided in this chapter of the manual, are synopses of other street storage studies, designs and implementation. The intent is to use other examples as supplemental, mini-case studies which provide additional insight into street storage. Some of the additional examples were carried through to implementation while other did not move or have not yet moved past the feasibility stage. Nevertheless, each of the mini-case studies offers additional useful ideas and information that may be useful to municipal officials.

In the early 1980's, near the beginning of the Skokie project, Donohue and Associates personnel learned much about flow regulators from other communities. For example, research revealed that vortex regulators had been installed in at least a dozen Canadian and U.S. communities. Contacts were made with municipal personnel in six communities that had vortex regulator experience. Donohue personnel also communicated with Canadian and U.S. communities about their experience with other types of flow regulators (Donohue, 1984a, pp. 3-3 to 3-13).

Missing, at that time, were completed, or largely completed, street storage systems that included flow regulators, berms, surface and subsurface storage. The Skokie and Wilmette case studies in the previous chapter provide examples of largely completed street storage systems. This chapter's synopses of other projects which are, in effect, street storage systems, provide additional examples.

## **Cleveland, OH: Puritas Avenue - Rock River Drive Area**

### ***Background***

This mid 1980's investigation was undertaken primarily to "...evaluate the ability of the Hydro-Brake to effectively regulate specific design flows from stormwater storage structures to such an extent that receiving sewers could be protected from surcharging and creating CSO conditions" (Mathews et al., 1983, p. 2, see also Mathews et. al., 1984). Although the study focused on the Hydro-Brake, one of the commercially available flow regulators discussed earlier in Chapter 3, the study does provide insight into the street storage system.

The overall combined sewer study area covered 115 acres of medium density residential originally developed in the 1920's. Basement flooding caused by surcharging of combined sewers was a problem. Within this area, three subsurface tanks were constructed serving separate subareas having a total area of 9.0 acres (Mathews et al., 1983, p. 2). The three tanks were located within the street curb lines and above the combined sewers, that is, they were intended to be gravity devices and to temporarily store stormwater runoff. The three tanks were constructed of corrugated metal pipe (CMP). The first tank used 163 feet of 48 inch diameter CMP and provided 2000 cubic feet of storage. The second tank was formed from two parallel 87 by 63 inch corrugated metal arch pipes each 156 feet long for a total storage volume of 10,000 cubic feet. The third tank consisted of 170 feet of 95 by 67 inch corrugated metal arch pipe and contained 5,800 cubic feet of storage. Inlets conveyed stormwater to the subsurface tanks and flow regulators controlled flow out of the tanks (Mathews et al., 1983, pp. 12-15).

The study included:

- Filling and draining each tank to determine Hydro-Brake stage-discharge relationships.
- Monitoring of precipitation, water levels in tanks, and stormwater quality.
- Simulation of tank inflow and outflow hydrographs for design storms of prescribed recurrence intervals.
- Pre and post-construction surveys of area residents with emphasis on basement flooding.

### ***Results***

Numerous findings were reported. Some of the more significant observations relative to this manual are (Mathews et. al., 1984):

*Hydro-Brake regulated storage tanks are effective in alleviating sewer surcharge and basement flooding problems.*

*By reducing the peak flow in the sewer system, combined overflow pollutant loadings are reduced because the first flush effect is dampened.*

*For effective application of the Hydro-Brake regulated technology, the design approach must include accurate characterization of drainage areas and sewer hydraulics to properly identify site-specific release rate requirements. The level of control desired determines the required storage volume, and the characteristics of the site determine whether to employ above-grade or below-grade storage, or a combination thereof.*

*Where surface ponding is an acceptable form of stormwater storage, the application of Hydro-Brakes alone is more cost-effective than Hydro-Brakes used in conjunction with off-line, below-grade storage structures. Both applications, however, appear to be more cost-effective than the other evaluated alternatives where both surcharging and overflows are the prevailing problems.*

*During the first 18 months of operation, the Hydro-Brake control/detention structures exhibited minimal maintenance requirements. Solids deposition in the storage tanks was negligible and did not increase significantly with time.*

Potentially useful ideas and information drawn from this Cleveland, OH project include:

- Use of CMP for subsurface tanks.
- Reduction of the first flush effect.

- Desirability, from a cost perspective, of using on-street storage rather than below-street storage.
- The likely cost-effectiveness and multiple purpose benefits (reducing basement flooding and CSO's) of a street storage system.

## **Parma, OH: Ridge Road Area**

### ***Background***

Ridge Road area "...is a topographic "dished" shaped area (30 acres) situated within the lower portion of a 290 acre drainage system. The terrain in the watershed is hilly with deep valleys..." (Pisano, 1989). The 290 acre area is highly developed in that it contains 1200 homes and many commercial buildings. An over/under sewer system serves the area. This is a special form of a combined sewer system common throughout the Cleveland metropolitan area. The storm sewer is laid immediately above the typically smaller diameter sanitary sewer. The two sewers share the same trench and manholes and, therefore, there is a high likelihood of flow between the two conduits..

As explained by Pisano (1989), the 30 acre area, known as the Triangle:

*...endured severe basement flooding resulting from the surcharging sanitary sewers during heavy rainstorms (at least three to four episodes per year). The cause of surcharge stems from the undersized storm systems which cannot handle storm flows, [they] pressurize, surcharge and leak significant amounts of clear water into the rock filled "french drains" trench section. Since the sewer joints in the sanitary sewer are invariably cracked or broken, the surcharge condition within the rock filled trench adversely affects the sanitary sewer piping, ultimately resulting in basement flooding. Basement flooding in the Triangle is further exacerbated by the poor hydraulic outlet conditions of the local sanitary systems...*

Due to the rolling terrain, there are numerous "low valley pockets" throughout the entire 290 acre area. The storm drains are generally inadequate. Surface water which cannot

escape via major overload routes...  
accumulates and severe street flooding results.

Therefore, the 290 acre drainage basin, and especially the Triangle, experienced frequent and simultaneous basement and street flooding. The problems needed to be solved.

### ***Results***

One partial solution was "...to construct a large underground off-line detention basin for relieving the sanitary trunk sewer coming into the study area and to construct sanitary relief sewers throughout the Triangle." This \$2,200,000 project (mid 1980's costs) would solve only the basement flooding problem. The surface flooding problem would remain.

The alternative, which was implemented, is what is referred to in this manual as a street storage system. The system includes downspout disconnection, berms, reconstructed curbs, flow regulators, new catch basins, subsurface storage tanks, manhole rehabilitation, and relief sewers. Construction costs in 1984 totaled \$875,000 (or about \$3000 per acre in 1984 dollars) which is 40% of the cost of the partial solution.

According to Pisano (1989), "The project has mitigated surface water ponding and has provided basement flooding protection throughout the entire 290 acre area... Although not intended, spring sanitary sewer infiltration has been significantly reduced."

Possible valuable ideas and information based on the Parma, OH project are:

- Potential applicability of the street storage system to hilly terrain.
- Use of the street storage system to simultaneously mitigate basement and surface flooding.
- Cost effectiveness of the street storage system approach.

### **Chicago, IL: Jeffery Manor Neighborhood**

#### ***Background***

Jeffery Manor is a 470 acre CSS area on the southeast part of the City of Chicago. Residential land use dominates with commercial, industrial and undeveloped land on the perimeter. Streets have curb and gutter, are paved and most have sidewalks and tree lined parkways. Local combined sewers, owned by the City of Chicago, range from 10 to 42 inches in diameter, and discharge to MWRDGC interceptor sewers. The entire area is very flat (SEC Donohue, 1993).

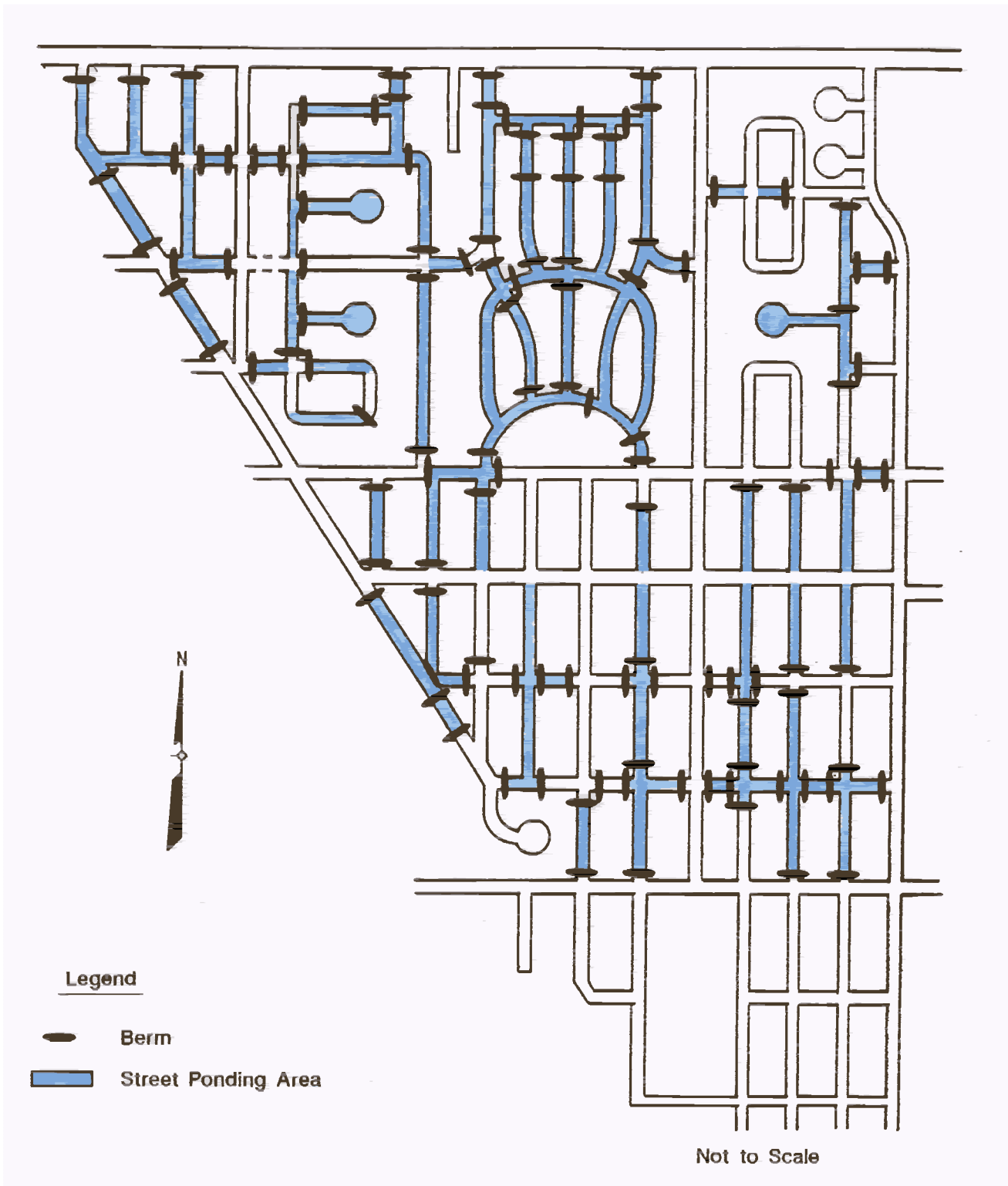
Jeffery Manor has a serious basement flooding problem caused by surcharging of the CSS. Local and interceptor sewers do not have the capacity needed to carry flows received during rainfall events. An additional exacerbating factor is excessive dry weather flow in interceptor sewers that originate outside of and flow through Jeffery Manor. Sewer crowns are about eight feet below street level and most basement floors are five to six feet below street level. Therefore, a few feet of surcharging above sewer crowns forces combined sewage into basements.

## **Results**

Results of the feasibility study, as quoted (parenthetical comments added) from SEC Donohue (1993, pp. 1-1 to 1-2) are:

*...a temporary street storage system would alleviate sewer surcharging in the Jeffery Manor area caused by overloading of the local collection system. The system was developed under the assumption of greatly reduced flows in the MWRDGC interceptor sewer entering the Jeffery Manor area. This reduction in flow will occur when tunnels or other relief sewer projects are constructed. However, if flows in the MWRDGC interceptor continue at current levels, the proposed street storage system will provide some relief to the existing flooding problem, but will not perform to its maximum capability.*

*The analysis for the five-year storm event showed that the storage required to eliminate sewer surcharging is 455,280 cubic feet (970 cubic feet per acre). The proposed temporary street ponding system entails development of ponding areas on 74 city blocks ...to provide 328,570 cubic feet of storage. The ponded stormwater would be held in place by 120 berms to be constructed across the streets (See Figure 4-1). Construction required for*



**Figure 4-1.** Street storage system proposed for the Jeffery Manor neighborhood in Chicago, IL (Source: SEC Donohue, 1993, p. 5-3).

*implementation consists of berm construction, removal of existing stormwater inlets and installation of new inlets with flow restrictors.*

*The estimated construction cost for the street storage components is \$1,860,000 (or \$3960 per acre in 1993 dollars).*

*Although temporary ponding alone will greatly improve the system capacity in Jeffery Manor, additional facilities are required to provide a full five-year level of protection. Approximately 60,000 cubic feet of additional storage is needed in the southern part of the neighborhood... This storage could possibly be provided on the property of a closed elementary school... Also a relief sewer is needed... To provide a five-year level of protection for the area after flows in the MWRDGC interceptor are reduced by other projects, street ponding, other storage and a relief sewer are required at a probable construction cost of \$2,481,600 (or \$5280 per acre in 1993 dollars)... Street storage reduces the required capacity of relief sewers, and can result in millions of dollars in savings for construction of sewers.*

The recommended project has not been implemented. Possibly useful ideas and information drawn from the Jeffery Manor feasibility study are:

- The need to address interceptor sewer capacity as affected by contributions from outside of the CSS area.
- Cost effectiveness of the street storage system approach.

## **CHAPTER 5**

### **REGULATORY AND FINANCIAL FRAMEWORK: COMPLYING WITH REGULATIONS AND FUNDING CONSTRUCTION**

#### **Motivated by Need But Subject to Regulatory and Financial Constraints and Opportunities**

The principal reason to undertake the street storage projects in the communities of Skokie and Wilmette, IL was to solve the serious problems of widespread flooding of basements by combined sewage. Skokie and Wilmette had flooding problems that had grown and festered long enough and the time for action had arrived, regardless of regulatory requirements.

This stands in stark contrast to the situation in many CSS communities where projects are planned and implemented primarily to comply with regulations and court, administrative or consent orders intended to prevent pollution of receiving waters. The fundamental challenge in Skokie and Wilmette was to take basement flooding, a serious, widely shared local concern, and come up with an affordable alternative to the proposed unaffordable relief sewers.

The initial objective in Skokie and Wilmette was to create a project that solved several problems and package the project in such a way that it:

- Eliminated basement flooding
- Was compatible with MWRDGC policy
- Was affordable to the community
- Was supported by residents and users
- Was supported by state agencies which control NPDES compliance
- Might be eligible for outside capital agency funding.

With these objectives in mind, planning, design and construction could not proceed in a vacuum. Many challenges had to be met, not the least of which were regulatory requirements and related legal matters and the means by which construction would be financed to make the improvements affordable. Some of the regulatory framework

proved to be advantageous in that it offered opportunities to pursue certain funding options.

Regulatory and financial issues are discussed together in this chapter because they are highly interrelated. For example:

- Federal and state regulations sometimes define a community's eligibility for external funding in the form of loans and grants.
- Past state and federal funding programs required ties to NPDES compliance and schedules of implementation for identified construction projects. In the case of Skokie and Wilmette, both projects were originally expected to construct large relief sewers to flow into TARP. TARP was grant eligible and the large relief sewers were not.
- Working through the wastewater and stormwater permitting process brings together local, regional, state and federal agency personnel. This connection expands the local communities access to unique project technical solutions as well as access to alternative funding sources.
- Home rule jurisdiction, as defined by Illinois law, meant that Skokie's elected and appointed officials did not have to get new voter approval on some local borrowing. However, in the case of Skokie and Wilmette, focusing on basement flooding elimination made proceeding with the project easier at the local level.
- Should the agency permitting process result in the creation of an unaffordable project solution, the agency permitting staff themselves become advocates for special funding. That special funding can come from a change in program eligibilities or direct legislative appropriations.

Other crucial issues, such as analysis and design procedures, public involvement, and inspection and maintenance are discussed in, respectively, Chapters 3, 6, and 7.

The next three major sections of this chapter focus primarily on complying with federal and state regulations and obtaining funding through federal and state programs. Sources for these sections are Roecker (1993, 1997, 1998a, and 1998b) plus additional sources cited within these sections.

## **Federal and State Regulatory and Funding Framework Within Which Skokie and Wilmette Functioned**

During the late 1970's, the Skokie and Wilmette combined sewer systems were expected to be reconstructed and connected to the future Chicago TARP project. A CWA Section 201 Facility Plan was prepared for both Skokie and Wilmette which showed the cost of combined sewer correction program, consisting of large relief sewers, to be very expensive. In the case of Skokie, the estimate was \$100,000,000 based on 1980 dollars. Because of TARP's need for construction capital and the MWRDGC's ability to win USEPA Construction Grant eligibility for the TARP project, Skokie, Wilmette and all other MWRDGC contract communities combined sewer separation projects were classified as ineligible for grant monies.

This ineligibility determination and the continued basement flooding stalled remedial action in Skokie and Wilmette until affordable alternatives could be developed. In the early 1980's, Skokie began looking for alternatives to the construction of relief sewers. Working with their engineering firm, they began looking at their challenge in terms of a stormwater management problem, rather than a relief sewer problem. This process resulted in the creation of the Skokie street storage system approach.

Meetings were held at the state to review the concept and determine how Skokie and the state could create a partnership. The partnership was necessary to change the regulatory requirements associated with the existing CWA Section 201 Facility Plan and to try to find a way to change or eliminate current funding ineligibility determinations. Initial meetings with the state focused on the following;

- Change the regulatory requirements associated with the previously approved CWA Section 201 Facility Plan to eliminate NPDES compliance issues associated with eliminating the relief sewers.
- Look for local, state or federal funding sources which could assist in demonstrating the new technologies or lower local cost impacts.
- Look for state level project support which would later help bring in other state and federal agency funding.

Today, the path cut by Skokie and followed by Wilmette, is different. The differences can be characterized as follows and can be used by others to assess the regulatory and financial process;

- The initial regulatory challenge facing Skokie and Wilmette related to TARP using all available USEPA Construction Grant dollars for their project and leaving the two communities with an NPDES requirement to build expensive relief sewers with no access to grant or low interest loan money. Today, large percentage grants are not available to projects like TARP and, therefore, communities are forced to focus on alternative, lower cost and smarter projects at their initial stages of project planning.
- The USEPA Construction Grants program has been replaced with the

USEPA State Revolving Fund (SRF) program. In general, this program provides low interest loans which must be paid back by the communities. A new sense of fiscal responsibility has entered projects which has resulted in longer term phased projects that become more affordable to the users.

- Demonstration projects, like Skokie and Wilmette, have become showcases of what stormwater management can accomplish in CSS and how it can save costs. More alternative technologies are becoming available to those who seek them.
- At the national level, the U.S. Congress has begun providing direct grant assistance to those projects which can demonstrate unique qualities or have unique characteristics. Most recently, successful projects tend to deal with the large issue of “watersheds” as opposed to single issue wastewater or stormwater challenges. The Skokie and Wilmette projects provide good examples of a multi purpose, watershed-based approach.

## **Today’s Regulatory and Funding Framework: Review of Outside Capital Funding Programs, Techniques and Strategies**

### ***Overview***

Since the 1950's, the U.S. Congress has provided capital funding for municipal water related infrastructure. The capital funding assistance has ranged from full project grants to subsidized long term loans. In the recent past, communities and authorities have found that their water related projects have become more expensive and government funding has diminished.

Based on recent Congressional actions, the future of state and federal sponsored water related funding programs and initiatives are becoming known. That future includes continued capital water related project funding opportunities for those communities and projects that meet the criteria of a changing funding landscape.

Ideas, suggestions and insights contained in this chapter provide the tools needed by communities to win needed capital water related funding. Addressed here is the movement of available local, state and federal funds through existing and proposed water related funding programs. Presented is information on the location of both traditional and nontraditional funding opportunities. Communities are encouraged to expand their water related project objectives to match the funding program objectives. Both state and federal funding program objectives are highlighted in this chapter to give community leaders important strategic information that can save time in review of possible funding avenues.

### ***Outside Capital Funding from Users***

The creative use of "special assessments" and "developer funds" offer unique capital funding opportunities. Use of both "special assessments" and "developer funds" can accomplish the following:

- The ability to assess acreage that is receiving a benefit from an area-wide project. In the case of an urban stormwater project, area-wide benefit can easily be defined and assessed on a more uniform basis than the traditional per-foot basis.
- The ability to assess the capacity of a storage or treatment facility to all users of the facilities on a uniform basis.
- Since "special assessments" are property liens, federal agencies are available to pay the assessments for the poor and elderly. Programs continue to provide monies for these special user groups to make the improvements affordable.
- Including the needs of developers as a project planning objective can enhance the project's usefulness, and bring a secondary benefit of outside funding from the developer. Long term phased projects tend to have the time available to search out these developers and negotiate reasonable financial contributions which benefit the developer and the community.

In the past several years, there is increased concern with making sure that all project "stakeholders" are paying their fair share. In developing an outside capital funding strategy, community leaders should make sure that all those benefitting or those who will benefit are accounted for.

### ***Outside Capital Funding from State and Federal Agencies***

In order to understand what agency funds are available, a community must learn why a agency provides funding. The following five points were developed from experience and provide some insights:

- Funding agencies fund their program objectives, not a community's project
- A community should develop its project's uniqueness during planning
- Keep working with the agency until someone says "maybe"
- Once funding is obtained, other agencies will follow
- Spend some time getting to know representatives of agencies

To reiterate, of all the issues that are important to winning outside capital funding, the single most important issue is understanding the funding program objective. As community leaders start thinking about outside agency funding, they should define how

their project will help the agency further its objectives.

The following list of funding programs contain current (1999) information regarding their objective, funding, administration, and current program status. These programs provide more than 90% of water related infrastructure funding throughout the country.

# U.S. Department of Agriculture (USDA), Rural Utilities Service (RUS) & Rural Housing Service (RHS).

Objective: To provide safe and sanitary housing, including water related facilities to small, rural municipalities ( less than 10,000 pop.) serving lower income persons.

Funding: FY 1999 funding levels were \$763,977,000 in low interest loans and \$500,000,000 in direct grants for project costs and \$25,000,000 in direct loans and \$25,000,000 in direct grants to low income elderly rural home owners for special assessments.

Administration: Through a federal agency state headquarters office and several district offices. The district offices review, screen and recommend individual projects to the state office. If the state allocation is committed, a state can submit a project to a national office for special funding consideration.

Status: These programs continue to receive increased funding. The district staff engineers provide a very detailed review of proposed infrastructure and work to lower capital costs and limit eligibilities on each project.

# U.S. Department of Housing & Urban Development Block Grant Program (HUD).

Objective: To provide viable urban communities with decent housing, a suitable living environment and expanding economic opportunities for low to moderate income residents.

Funding: FY 1999 set funding levels of \$3,103,100,000 for their large community entitlement program and \$62,222,000 for their small community block grant program.

Administration: Through a state agency normally located in the state capital.

Status: Past historic influence by Congress is said to have ended. Entitlement recipients tend to receive small allotments that are spread over numerous competing infrastructure needs with little money available for new water related infrastructure, while the state-wide small community competition tends to provide a more meaningful opportunity for water related funding.

# U.S. Department of Commerce Economic Development Administration (EDA).

Objective: To promote long-term economic development and assist in the construction of infrastructure, including water related facilities, needed to initiate and encourage the creation or retention of permanent jobs

Funding: FY 1999 saw program funding of \$160,000,000 for this program.

Administration: Through a federal agency headquartered in the federal regional city with a very small state or multi state office. In addition, individual states also have their own version of this job creation program that can provide direct state assistance to worthy projects.

Status: While EDA was slated for termination by the 104th Congress, it remains intact. Before funding water related infrastructure, EDA will want very detailed information from the job creator and limits funding to projects that generally cost less than \$10,000 per permanent job created.

# U.S. Environmental Protection Agency (USEPA).

Objective: To provide financial incentives to communities to obtain and maintain NPDES compliance and provide a long term source of financing for water related infrastructure.

Funding: FY 1999 saw program funding of \$2,125,000,000 for their water related State Revolving Loan programs with additional grant monies available from the USEPA Budget itself.

Administration: Through a federal agency headquartered in the federal regional city with direct allocation of loan and grant monies to individual state pollution control agencies.

Status: The State Revolving Fund programs are viable funding programs and are beginning to expand eligibilities for watershed projects. Reauthorization of the Clean Water Act was pending as of early 1999. However, the reauthorization is expected to further expansion of the eligibilities to innovative watershed programs that meet the objectives of pollution reduction together with flood protection.

In addition to the USEPA's State Revolving Fund program several areas of the U.S. Budget contain demonstration and implementation funding programs that can provide grant assistance to projects that meet the specific funding objective contained in that particular section. The USEPA (1993, EPA-814) provides the list of funding sources which follows. Note: Section numbers refer to the Section of the existing Clean Water Act and the numbers in parentheses refers to the funding program as described by the Executive Office of the President and U.S. General Services Administration (U. S. GSA, 1998).

- Section 106 (66.419): This program provided state and interstate agencies and Indian tribes with more than \$115,000,000 in 1999 for prevention and abatement of surface and groundwater pollution.
- Section 604(b) (66.454): This program provided States with \$12,000,000 in 1999 to carry out water quality management planning.

- Section 603(d) (66.458): This program provides States with up to 4% of their State Revolving Fund (SRF) allocation to manage their programs. Nationally this amounts to more than \$80 million annually, and if the State's SRF program involves water resource projects, the administration of these water resource projects can come from this fund.
- Section 319(h) (66.460): This program provided \$200,000,000 in 1999 to State-designated lead non-point source (NPS) agencies to fund implementation or construction of water resource related practices or infrastructure. The 1999 federal allocation represents a 100% increase over 1998.
- Section 320(g) (66.456): This program provided \$12,300,000 in 1999 to any agency or individual for planning activities in designated estuaries.
- Section 104(b)(3) (66.463): This program provided \$19,000,000 in 1999 to any agency or individual for one to two year demonstration type projects, including combined sewer overflow and stormwater discharge control programs.
- Regional Initiatives: The USEPA regions spend in the area of \$2 to \$4 million annually on projects that address watershed protection. Communities can obtain a listing of current objectives from their regional USEPA office.

Working through these federal agencies and their state counterparts will provide community leaders with an understanding of the administrative funding possibilities for both current and future water related projects. In addition, the effort will produce the background information needed by a community to consider taking their project to the next step in the funding road. That step is the U.S. Congress.

### ***Outside Capital Funding from the U.S. Congress: Direct Legislation***

Over the past several years, a growing number of communities have sought direct funding of their projects from Congress through the U.S. Congress' appropriations process. In addition, various State Legislatures have begun providing direct funding of special and unique projects.

Since 1992, the U.S. Congress has provided \$3,579,425,000 in direct grants for water, watershed, groundwater and wastewater projects across the nation. If a community works through the existing local, state and federal agency funding programs and the project is still truly unaffordable or if it has some unique feature that distinguishes it from other projects attempting to accomplish the same objectives, elected officials can help.

Certain projects may fall through the cracks either by poor management or circumstances beyond their control. The U. S. democratic process has a strong sense of fairness and when a case can be made demonstrating that the project has not had a fair shake for available public funds, both the state and federal legislatures can help.

Special attention to the issues of the day and the concept of "fairness" leads to success in the legislative arena. When dealing with its legislature, community leaders should keep the following objectives in mind:

- Legislatures provide direct funding to win favor with large population areas for future political purposes by correcting an actual or perceived public policy injustice and removing unreasonable regulatory barriers which preclude sound projects from proceeding.
- Legislatures provide direct funding to correct actual or perceived public policy injustices for a project which would have been eligible for significant grant funds in the past and was delayed beyond the control of the community.

As can be seen from a review of these two concepts, the key is to have spent the time to review all funding options and have a project packaged to the point that congressional funding is the last, but potentially promising resort. Using the information provided in this chapter as an overall checklist for local, state, and federal agency funding opportunities will serve communities well in covering the "other funding" bases. Spending appropriate time to prepare a well written, concise project history, scope and objectives document will serve to focus a community's project objective. The community, its engineer, and state and congressional representatives should be involved in the packaging process.

Below is a checklist of items to review before a community goes to the U.S. Congress with its project. Community leaders should remember that they are looking to get their representative's attention and have their project meet the objectives of the current line item funding written and unwritten criteria.

#### I. Project factors to be completed before taking a project to U.S. Congress

##### A. Past site, environmental, and water quality issues addressed

1. The project is planned and on its way to being designed.
2. The community has reviewed other funding and understands why it is not available.

3. The state has supported the project in writing and has given it high priority.
- B. Past agency issues have been addressed
  1. The community addressed state concerns raised during the planning process.
  2. The community has or is continuing to work to secure all project permits.
- C. The project is packaged
  1. Unique project qualities have been determined.
  2. The community knows all its lost opportunities for funding and the reasons.
  3. The community has a well written one to two page summary describing the project and needs.
  4. Parallels to past congressionally funded projects have been developed by the community.
  5. The project's objectives have been packaged in a user-friendly format.

## II. Recommended Washington-based activities

- A. Develop the right team to present and monitor congressional actions
  1. Set up a team representing the community that includes:
    - State congressional delegation representative
    - Local elected representative
    - Governor's office
    - Project owner's staff
    - Consulting engineer
    - Governmental affairs manager or consultant.
  2. Make specific assignments to team members.
- B. Make sure that the team understands the project and its objectives.
- C. Meet with and/or communicate frequently with the community's congressional delegation
- D. Use the team's past experience to create new relationships with influential congressional leaders, appropriate committee members and staff
- E. Monitor the schedule of both the authorizing and appropriations committees
- F. Develop, manage, and communicate with project team members frequently
- G. Make responding to questions, inquiries, or requests a high priority

## III. When a community "wins" funding

- A. Make sure that the entire congressional delegation gets credit
- B. Work with the appropriate funding agency in the grant release process
  - 1. That agency has control over grant percentages, the application or non-application of rules, regulations, and program guidance.
  - 2. Most funding agencies burdened with the grant release process are understaffed and need community technical assistance to move quickly.
  - 3. Be willing to share a small portion of the grant to cover necessary funding of agency administrative costs of grant administration.
  - 4. Keep very accurate records during the project because federal audits are likely years after the project is complete.

### **Initial Capital Funding for the Skokie Street Storage System**

As discussed earlier in this chapter, Skokie's initial capital funding plan had the following two objectives:

- Lessen the cost or eliminate the need to construct the \$100,000,000 relief sewer system that was recommended by its existing CWA Section 201 Facility Plan.
- Develop an innovative technical alternative to the relief sewers, work with State and Federal agencies to win approval and secure some outside funding to make the alternative affordable.

Skokie began work with the regional consulting engineering firm Donohue and Associates, Inc., of Milwaukee, WI (now Earth Tech, with corporate offices in Long Beach, CA), who developed the innovative street storage system. Once this system was documented in a feasibility study and the estimated capital cost was shown to be only a quarter to a third of the cost of the relief sewers, Skokie called a meeting with the State of Illinois.

The state was impressed with the technical approach and quickly realized that this innovative technical alternative could be applied to other communities in the area and result in a significant lowering of capital infrastructure cost. With this being the case, the state became a partner in the project and began working with Skokie to find ways to assist with making the project a reality.

While the USEPA's Construction Grants Program specifically made the relief sewer alternative an ineligible project, the state had begun work on the new USEPA State Revolving Loan Program which allowed the State more flexibility in making eligibility decisions. After reviewing the water quality impacts and evaluating the technical merits of the project, the state made the project and technology eligible for its low interest loan program. Low interest loans were important catalysts in both the Skokie and Wilmette

street storage projects.

The new funding program was entitled the “State of Illinois Water Pollution Control Revolving Fund” (WPCRF). At its inception, it offered communities 20 year loan rates equal to one-half the interest rate for which the State of Illinois could borrow monies.

Once Skokie began the project, it recognized that expanding the project objectives and building a partnership with the state helped bring in outside capital to lower the cost of the project and create a new project partner. This process was continued with the State of Illinois Department of Transportation (IDOT). Skokie had a need to build street storage infrastructure in and near to IDOT facilities. Working with IDOT and demonstrating the positive impact of the street storage project on their facilities resulted in the Village’s receipt of additional direct grant dollars from the IDOT’s own funding programs. Another phase of Skokie’s partnership with the state is grants received under the Build Illinois program.

In the fourteen years Skokie has continued with the project, they have used a combination of SRF loan monies, direct grant monies from the State of Illinois Department Transportation, Build Illinois grants, and General Obligation local bond monies to bring the project to where it is today. A general breakdown of these four funding sources, is as follows:

•	Water Pollution Control Revolving Fund	=	\$18,700,000
•	IDOT grants	=	1,100,000
•	Build Illinois grant	=	500,000
•	General Obligation bonding	=	<u>56,000,000</u>
•	Total		\$76,300,000

### **On-Going Local Capital Funding of the Skokie Street Storage System Through the Bond Market**

Fishman (1998) reviewed the history of the Skokie street storage project with emphasis on how it was financed on the local, non-agency front. As the project neared completion in 1998, Fishman’s paper provides a contemporary, insightful, outsider’s view of the systematic, prudent and persistent process followed by community leaders to use the municipal bond market to finance project costs outside of agency funding sources. The paper reviews the advantages of the phased implementation of the system over an approximately 14 year period and provides insights into the marketability and the investors desire to purchase municipal bonds for projects such as this.

Even though the cumulative capital cost of the innovative street storage system was to

be only about one-third the cost of more traditional sewer separation approaches, this was the most expensive project ever undertaken by the community. Skokie faced a great financial challenge.

From the outset, according to Fishman (1998, p. 181), Skokie enjoyed at least two project financing advantages. First, the community had a high credit rating so that bond issues typically drew multiple bidders. This yielded favorable interest rates. Second, as an Illinois home-rule community, the community leaders did not have to get voter approval for general obligation bonding.

As part of the street storage financing process, the community retained an individual financial advisor. According to Fishman (1998, p. 182), the financial advisor's responsibility was:

*...to structure bond offerings on behalf of issues so that they are legal and fair, as well as attractive to both investors and dealers. Then, at a pre-set time and under terms put forth in his offering documents, he invites would-be dealers to bid on the issue.*

Moody's Investors Service was retained by Skokie to determine the community's financial health. This is where the new and innovative nature of the street storage system could have affected the capital financing process. Fishman (1998, p. 182) explains that the soundness of any particular project in a community usually doesn't affect the financial health assessment conducted by Moody's and other rating agencies:

*...but in Skokie's case, the review would have to account for the largely experimental and expensive technology involved in the project. ...Moody's even made a few house calls to get a feel for the intangibles that might not be captured by the town's financials.*

Apparently the "experimental" technology passed muster. Skokie funded the capital cost of the project largely with a series of eight general-obligation bonds, the first of which was issued in 1985. A total of \$56 million was borrowed at interest rates ranging from 4.5 to 7.2 percent. In 1998, Skokie:

*...completed the last round of borrowing. Seven bidders sought to issue bonds, and Skokie got the lowest interest rates since the project began over a decade ago (Fishman, 1998, p. 185).*

## **Skokie Downspout Disconnection Ordinance and Program**

As suggested in the preceding sections of this chapter, federal and state regulations often require that a community undertake costly projects. On the positive side, these regulations also provide the creative, proactive community with opportunities for outside funding.

While a community has little if any control over state and federal regulations, it does have overall control over the creation and enforcement of local regulations. Skokie created and enforced a special local regulation to successfully implement downspout disconnection, the first concrete step in its program to mitigate basement flooding caused by surcharging of combined sewers. Described here is the community's systematic program, which started with information gathering and education, ended with strict enforcements, and resulted in the disconnection of essentially all downspouts. Portions of Skokie's approach may be useful to other communities.

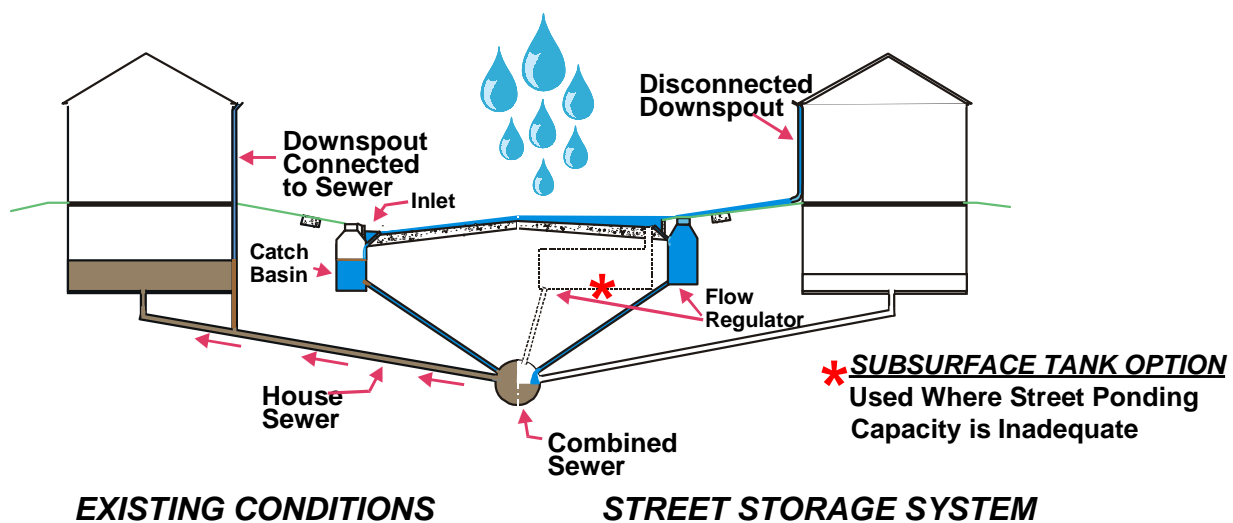
### ***The Downspout Problem***

As shown in Figure 5-1, when downspouts are connected to the house sewer, they permit roof water to directly and immediately enter the CSS. This aggravates combined sewer surcharging and basement flooding problems.

### ***The Downspout Solution***

The adverse effects of directly connected downspouts can be partly mitigated by disconnection the downspouts at ground level and directing their outlets toward landscaped areas. A photograph of a disconnected downspout is provided as Figure 5-2.

Paintal (1981), in his study of Skokie's ESSD, concluded that "for short duration storms the disconnection of downspouts from the sewer system reduces the flow in the sewer significantly if the flow from the downspouts is directed to lawns and other porous areas." Skokie's 1974 study of a pilot area concluded that downspout disconnection would substantially reduce the hydraulic load on the combined sewer system.



**Figure 5-1.** Downspouts connected to the house sewer, as shown on the left side, permit roof water to directly and immediately enter the combined sewer system and increase surcharging.



**Figure 5-2.** A disconnected downspout.

## ***Educational Value***

Even if downspout disconnection does not achieve a major reduction in the load on a combined sewer system, it can have a positive community-wide educational effect. Success of a downspout disconnection program requires participation, that is, specific action, by essentially all property owners. Accordingly, they are likely to gain additional understanding of the cause and effect relationship between stormwater runoff and surcharging of the CSS. Armed with this knowledge, citizens are more likely to understand the need for and give support to other much more costly components of a street storage system. Examples of those other components are berms, flow regulators, and underground tanks.

## ***Downspout Disconnection Process Used in Skokie***

This description is based on a paper by Walesh and Schoeffman (1984) which was presented near the end of the disconnection program. The Skokie program began in a regulatory manner with the September 1981 passage by the Board of Trustees of an ordinance requiring the disconnection of all downspouts on one and two family residences.

However, the initial strategy was to gather information and encourage volunteer action, rather than emphasize enforcement. Questionnaires were sent to every involved residence. This questionnaire set the groundwork for the subsequent two year implementation effort. Residents were asked if their downspouts were already disconnected, whether they needed assistance or advice, and whether they felt that special circumstances made them eligible for an exception from the ordinance.

Based on the response from this survey, Skokie personnel began a comprehensive program of assistance and inspection to determine where exceptions could be granted and to find where compliance had been achieved. The initial inspection effort found that volunteer action in response to previous recommendations to disconnect downspouts had resulted in almost 50% compliance with the ordinance before its passage.

In order to make the program manageable, residential areas of the community were broken down into 21 housing districts, each containing approximately 700 residences and covering an area of approximately one-half square mile. Each housing district was dealt with separately and given a specific compliance date. Owners or occupants of residences determined through inspection to be violating the ordinance were notified by letter of the compliance date for their district. After expiration of the compliance date, another inspection was made and a "warning citation" left at the residence by the inspector. Two weeks after this warning, a final letter was sent to all non-complying residents and citations requiring court appearances were issued.

For a two year period, except during winter months, this process continued. At the conclusion of the program, 99.9% compliance was achieved in that all but 18 residences out of the total of almost 14,000 satisfied the requirements. A total of 169 citations were issued requiring court action and 19 judgments of up to \$500 were entered by the court.

A review of the small number of exceptions granted under the ordinance indicates that more than 90% of the roof water from one and two family homes in Skokie were disconnected from the sewer systems. One reason for this small number of exceptions is the specific criteria used to evaluate the need for an exception. Exceptions were granted only if the downspout water could not be directed to a location where it would drain away from all building structures with the use of an extension up to ten feet long or where a necessary downspout extension would block a sidewalk or driveway.

### **Skokie Stormwater Control Ordinance**

As explained by Donohue (1987a, p. 3-2):

*Skokie adopted a stormwater control ordinance in August 1977. This ordinance requires that all new development limit the peak runoff rate from the site to that of an undeveloped 2-year frequency storm ( $C = 0.15$ ). Excess stormwater runoff, as determined by the difference between the stormwater runoff from the undeveloped area with a 2-year storm and from the developed area with a 100-year storm, shall be stored onsite in a stormwater retention or detention facility. All development that existed prior to the effective date of the ordinance was exempt from the stormwater control requirement except certain off-street parking facilities and developments that are destroyed or improved by greater than 50 percent of the original value of the structure before such damages were incurred or improvements were made. The ordinance also outlines minimum design and construction criteria for onsite stormwater retention/detention facilities and discusses maintenance, administration, and enforcement.*

This ordinance focuses primarily on new development but also applied to redevelopment. Given that Skokie is essentially fully developed, as are many CSS areas or communities, stormwater ordinances intended to prevent increased runoff rates from new development will not typically have remedial effects. They can, however, prevent aggravation of existing surcharging and related problems.

Skokie's stormwater ordinance provided a "safety factor" for the street storage system.

In designing the street storage system to prevent combined sewer surcharging, the ordinance allowed the assumption that any redevelopment in the community would be restricted by the two year criterion.

### **Regulations of the Metropolitan Water Reclamation District of Greater Chicago**

The “Manual of Procedures for Administration of the Sewer Permit Ordinance” was adopted by the MWRDGC in 1970. Included are guidelines and criteria for the design of sewerage within the agency’s jurisdictional area. An MWRDGC permit is required for a sewer system to discharge to the agency’s system. The following provisions (quoted from Donohue, 1982a, pp. 28-29) related to CSS:

1. Complete separation of sewers shall be provided within the property lines.
2. Detention shall be provided and/or permanent constrictions shall be built on the stormwater sewer system to control flow into the existing combined system in accordance with the requirements of the local government.
3. All downspouts or roof drains shall be discharged onto the ground or be connected to storm or combined sewer.
4. Footing drains shall be connected to sump pumps and discharge shall be made into storm sewers, combined sewers, or drainage ditches.
5. Floor drains in basements shall be connected to sump pumps and discharged to sanitary or combined sewers.
6. Sump pumps shall be used for only one function, either to discharge stormwater or to discharge sanitary sewage. If both functions are used in one building, two pumps are required.

## **CHAPTER 6**

### **STAKEHOLDER INVOLVEMENT**

#### **Two Public Works Challenges**

Two major challenges face today's public works personnel. The first is the challenge of finding cost-effective solutions to increasingly complicated urban problems. The second is communicating effectively with the public, recognizing the public's increasingly elevated expectations relative to public facilities and services and the public's growing understanding of technology and the environment. A premise of this chapter is that many and varied stakeholders want to be involved in public works decisions and should be given the opportunity to do so.

In retrospect, there was great need for meaningful communication with stakeholders in the Skokie and Wilmette street storage projects. Two factors heightened the need for stakeholder involvement. First, the technology was very new, especially for Skokie. Second, many individuals, especially residents and business people scattered throughout the CSS, would be directly affected. These were not remote projects.

Interestingly, and fortunately, both Skokie and Wilmette recognized the need for intense communication. From the outset, both communities mounted proactive efforts to interact with stakeholders. These efforts apparently played a major role in the success of the two projects. As evidence of this, read the Chapter 8 summary of interviews and comments with Skokie and Wilmette officials.

#### **Purpose of this Chapter**

Given the apparent importance of stakeholder involvement in the two street storage projects described in this manual, the purpose of this chapter is to describe those efforts. This documentation may be helpful to other communities. While communities with a CSS should benefit from some of the specifics, many of the stakeholder involvement efforts in Skokie and Wilmette are applicable to a wide range of public works projects. Therefore, this chapter, unlike most other chapters of this manual, is not focused primarily on street storage systems.

## **A Characteristic of Wet Weather Problems: Widely Fluctuating Public Interest**

The interest of the public and some elected and appointed government officials in wet weather problems and opportunities tends to fluctuate widely, as illustrated in Figure 6-1. The fluctuations parallel the random nature of major meteorologic events. Interest usually is most intense during and immediately after a destructive problematic water event such as basement or surface flooding, or CSOs.

Later, typically months later, when the initial studies/plans/preliminary engineering are completed and recommendations made, interest has subsided. The zeal that commissioned the investigations is not complemented with similar zeal to implement the recommendations of those investigations. Maintaining stakeholder interest is one challenge of a stakeholder involvement program.

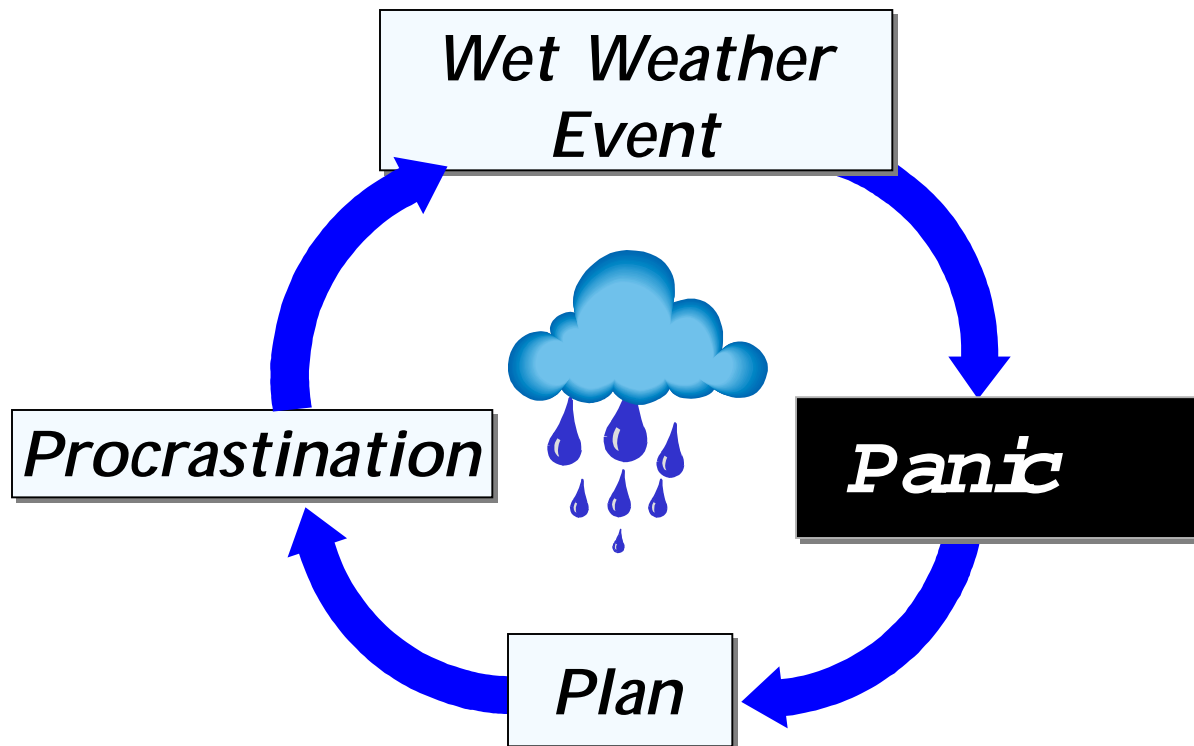
The widely fluctuating interest associated with wet weather problems contrasts with a more level and continuous concern with most other areas of public works and services. Examples are water supply pressure; condition of streets, especially presence of potholes; level of police protection; and quality of public schools. Once problems develop in these areas, they tend to persist and to receive persistent public attention until they are solved.

## **More on the Need for Stakeholder Involvement**

A public works effort that fails to include a stakeholder involvement program plans to fail. Although said over a century ago, and in an entirely different context, the following words of President Abraham Lincoln are appropriate: "With public sentiment, nothing can fail; without it nothing can succeed. Consequently, he who molds sentiment goes deeper than he who enacts statutes or pronounces decisions" (Helweg, 1985).

Grigg (1986) defines planning as "studying what to do" and distinguishes planning from decision making or "deciding what to do." The point is that studying and deciding are two different activities or processes, and, as exemplified by the preparation of a street storage plan, the studying and deciding processes are usually carried out by different groups. A team of professionals and technicians prepares the plan. Another group of primarily appointed and elected officials, usually influenced by the public, typically makes decisions based on the findings of the plan.

Because planning and deciding are different functions done by different groups, public works personnel and their consultants must not be so presumptuous as to think that their recommendations will be fully embraced by decision makers. The professionals can greatly enhance the probability of acceptance of the recommendations if the work is of high quality and if the professionals effectively communicate with all interested individuals and groups.



**Figure 6-1.** The “Hydroillogical” cycle

A public interaction program, or lack thereof, is often the principal reason for the successful implementation of a public works program or the failure to implement it. This observation is supported by the work of Kurz (1973) and Rubin and Carbajal-Quintas (1995) who describe six unsuccessful urban area planning efforts (not all water-related) and conclude why they were not implemented. Deficiencies identified include a lack of clearly presented objectives and standards; poor public involvement efforts; inadequate coordination between government units and agencies; and a myopic approach to the identification, development, and testing of alternatives. Kraft (1997) concludes that failure to build public consensus is the reason for the failure of several public projects that would have incorporated new ideas. Street storage is an example of a new idea. Kraft lists causative “common pitfalls” similar to the preceding deficiencies. Avoiding such deficiencies and pitfalls is the goal of a public interaction program, especially when new, innovative technology is contemplated.

Perry (1996) advocates the preceding ideas using a “pro and con” model of public communication. When the desirable “pro” approach is used, public works professionals are proactive, proficient, and pro-people. In the undesirable “con” mode, the situation is confrontational and confusing and messages are contrived.

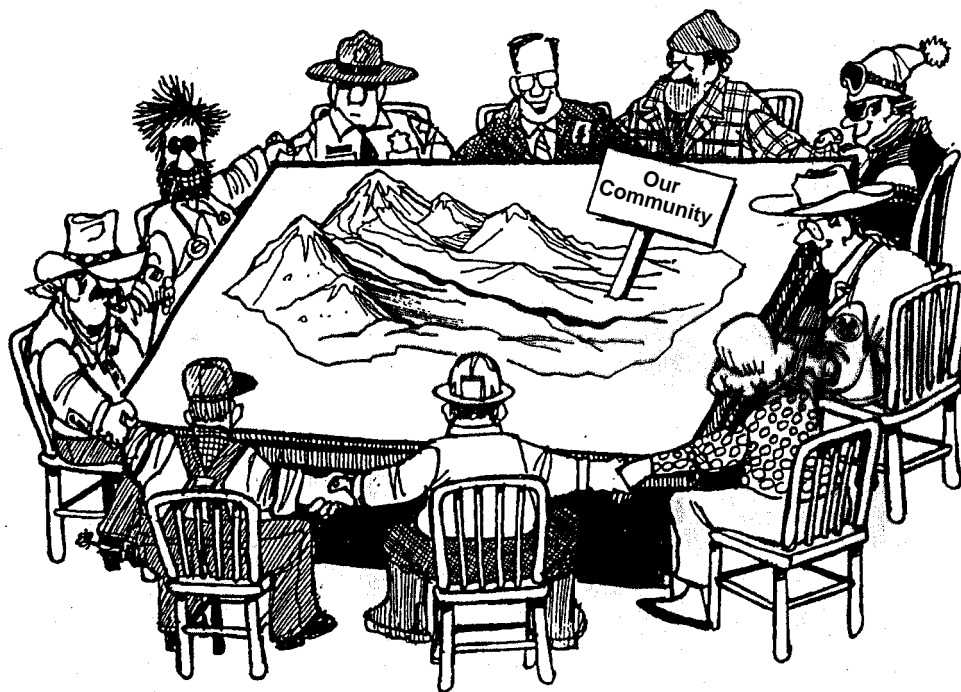
Herrin and Whitlock (1992) somewhat harshly, but perhaps accurately, suggest that the cause of some communication failures lies with engineers’, and perhaps other professionals’, formal and informal education. According to them:

*Engineers are taught very few skills in interpersonal relationships, much less those of public interface and involvement. We spend little, if any, time addressing it at our conferences and conventions. We then spend thousands of hours and millions of dollars defending our projects when threatened by delays and possible blockage by public intervention.*

As noted by Viessman (1989), public sector problems “cannot be solved in the technologic area only... Engineers must be society-wise as well as technology-wise.”

## **Identification of Stakeholders**

The success of a stakeholder involvement effort is determined more by the number of different, legitimate stakeholders involved than by the total number of individuals involved. Many subgroups with very different, often competing agendas typically constitute the stakeholders. Breadth of stakeholder representation and involvement is crucial as suggested by Figure 6-2.



**Figure 6-2.** Breadth of stakeholder involvement is crucial (Source: USEPA, 1997).

Public works officials should be especially wary of the temptation to exclude what they regard as “extremist” elements from the deliberation process. These groups have a right to be part of the process and to express their views. Attempts to exclude them are likely to aggravate matters and precipitate or elevate conflict. In addition to affording them their rights, inclusion of “extremist” organizations may lead to moderation of their positions as their representatives are gradually exposed to data and information developed during the management program and as they interact with spokespersons for other segments of the public.

Presented in Figure 6-3 is a likely set of stakeholders for a street storage project. Note the breadth of interests that are represented.

### **Types of Stakeholder Involvement**

Priscoli (1989) suggests that interaction between public works professionals and the public refers to a continuum of activities, programs, and techniques. The continuum ranges from proactive public involvement (e.g., public information, advisory groups, workshops) at one end of the spectrum to reactive conflict management (e.g., mediation, collaborative problem-solving, negotiation, and arbitration) at the other end. The preceding suggests that stakeholder involvement should employ many and varied programs and events.

Unfortunately, some professionals with public works responsibilities fail to appreciate the importance of the communication challenge, or they recognize the challenge but are not prepared to meet it. The traditional DAD approach, that is, public works professionals adopt a *decide-announce-defend* mentality, is no longer appropriate. The much more progressive and inclusive POP approach, that is, *public owns project*, is more likely to be effective given the changing nature of the public’s expectations and knowledge (Walesh, 1999).

Speaking directly to civil engineers, and indirectly to all public project professionals, Wakeman (1997) describes today’s situation this way: “...broad sections of today’s public are concerned, vocal, and actively engaged in the formulation and implementation of public policy, particularly policies regarding public facility construction projects. Today’s civil engineer must be ready to work on infrastructure projects from many more perspectives than were required in earlier years.”

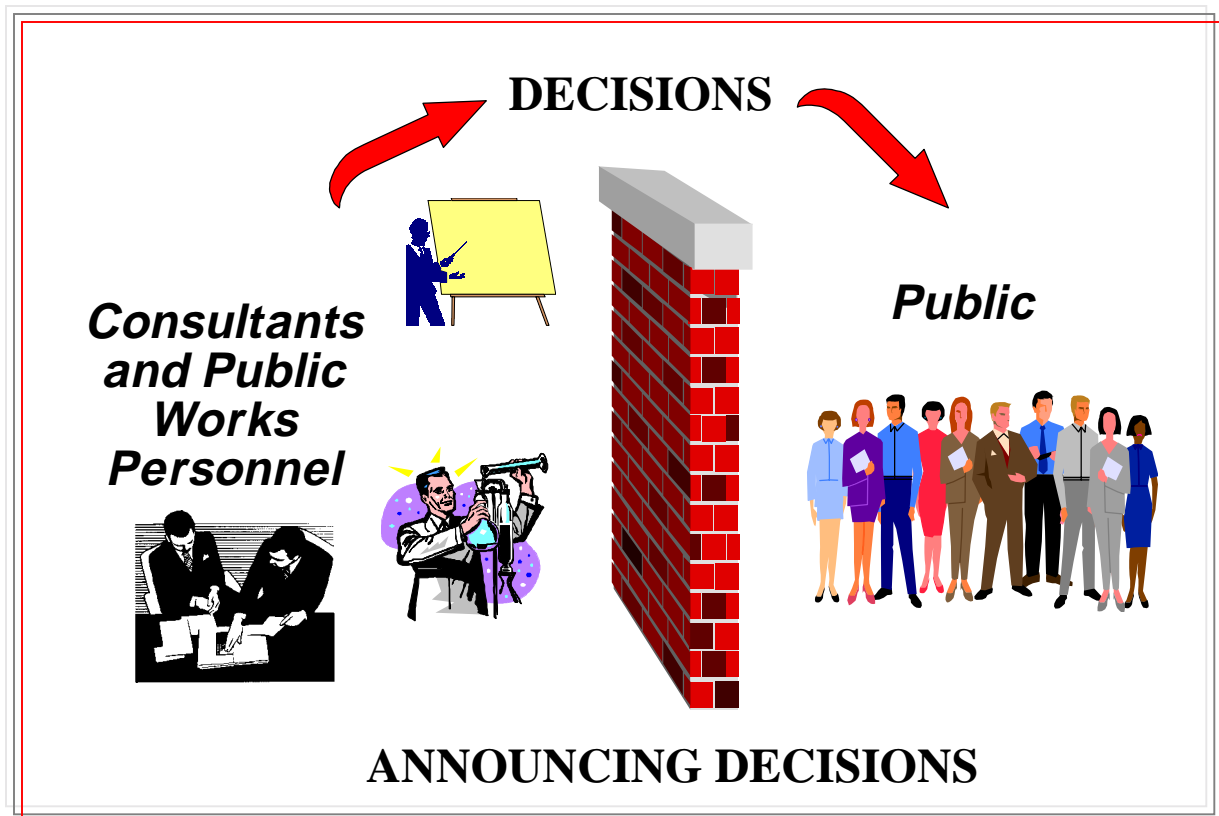
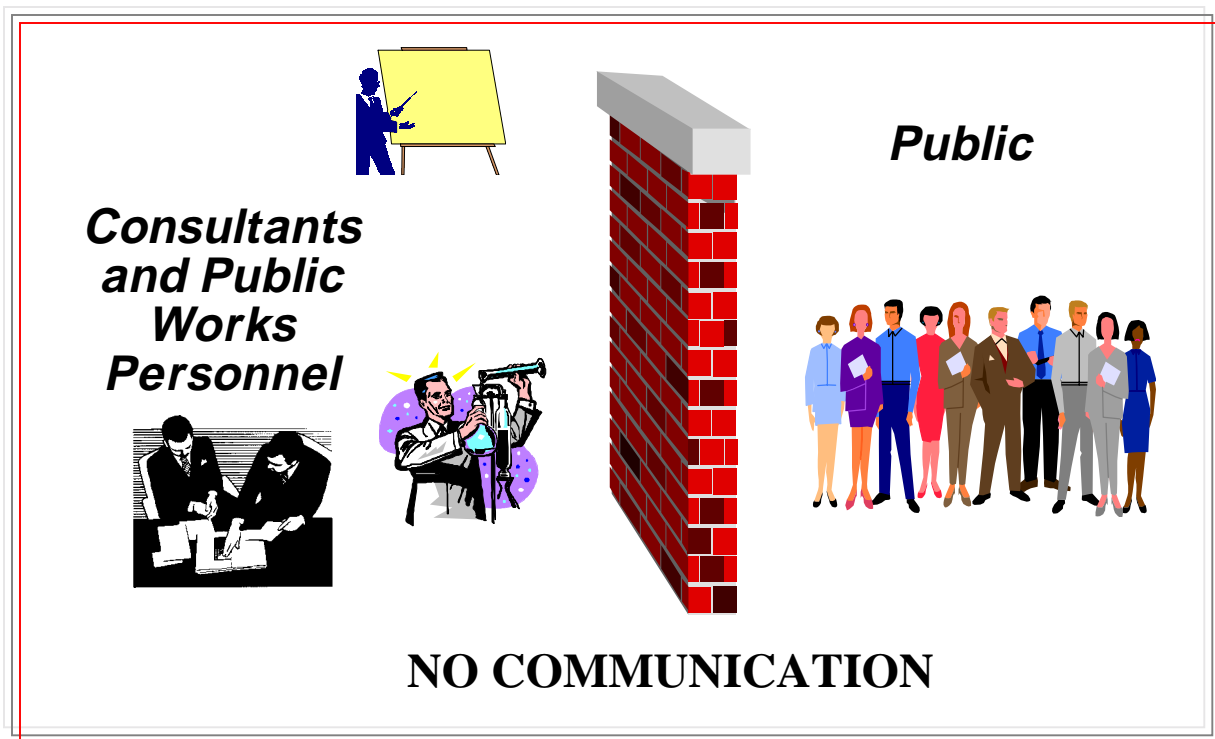
Furthermore, stakeholder involvement is explicitly intended to be an iterative, two-way process. The old DAD strategy is out. It is being replaced by the two-way POP strategy in which concerns, ideas, and information flow freely between water resource professionals and the individuals and organizations representing various interests. Public interaction goes way beyond no communication (Figure 6-4) and announcing decisions (Figure 6-4). Interaction even goes beyond public information (Figure 6-5),



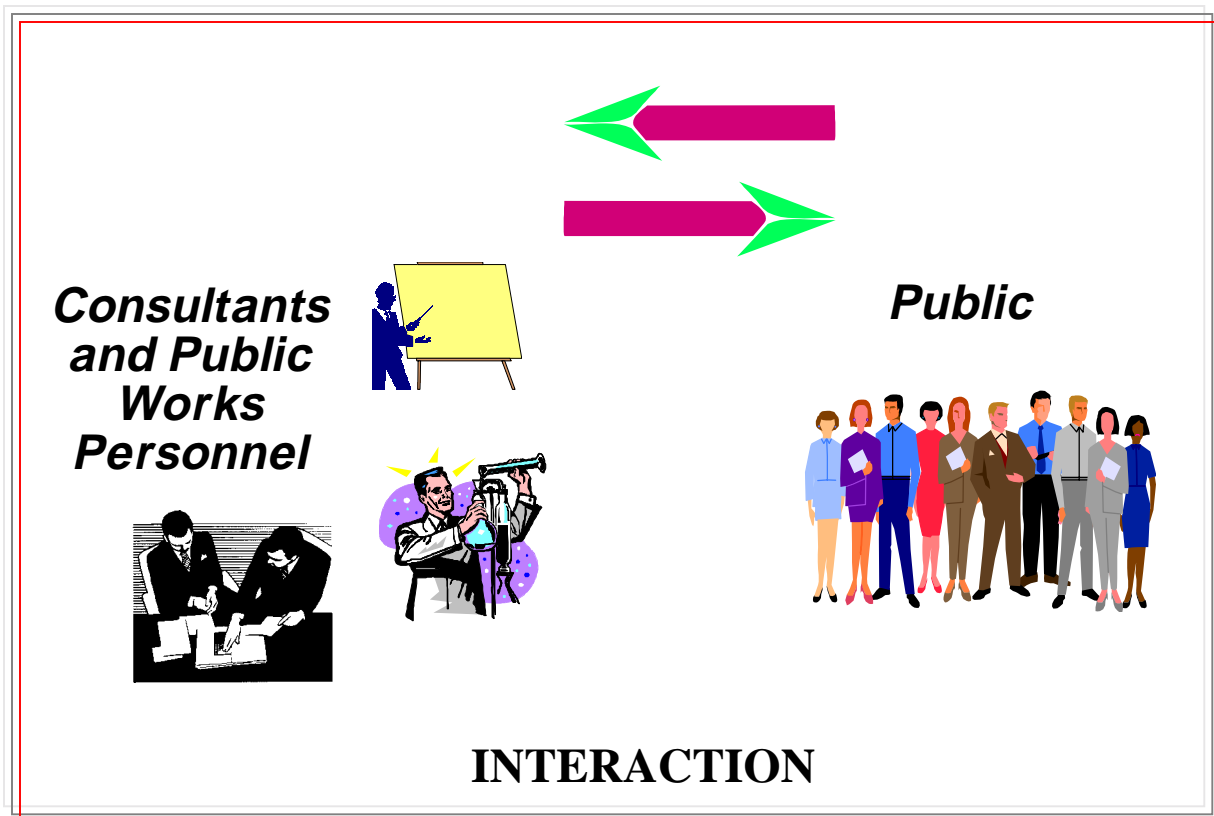
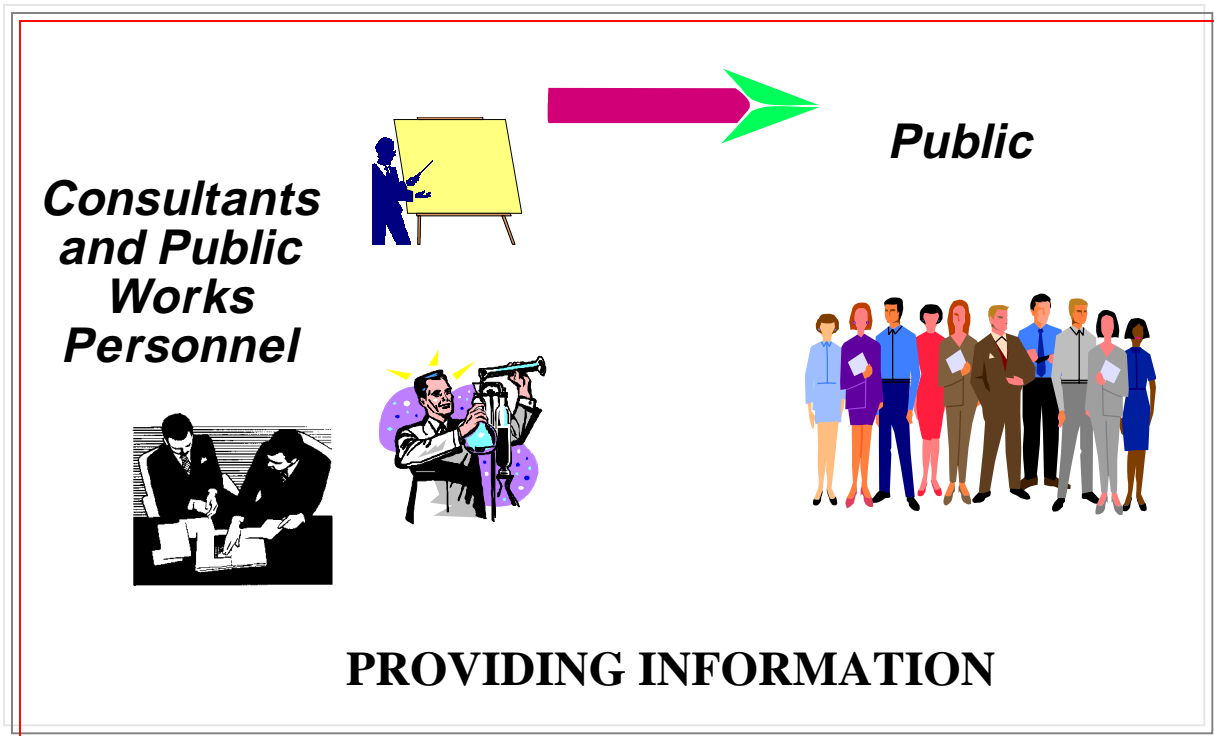
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1) Local, regional, state, and federal entities.

**Figure 6 - 3.** A street storage project is likely to have many stakeholders, all of whom should be involved from the outset.



**Figure 6-4.** No communication and announcing decisions are increasingly unacceptable ways of serving the public.



**Figure 6-5.** The goal in stakeholder involvement goes beyond providing information, it is meaningful interaction.

which implies one-way communication from water professionals to the public. Public interaction is truly two-way communication (Figure 6-5).

The importance of conducting the public interaction effort throughout a public works program—from beginning to end—must be emphasized. Astrack et al (1984), Rubin et al (1995) and Walesh (1993) emphasize the need to repeatedly interact with various elements of the public beginning on “Day 1” and extending throughout the process. In addition, the process should be highly visible to and easily accessible by the public. Sargent (1972) uses the term “fishbowl planning” to suggest frequent and open stakeholder involvement as the plan is being prepared.

The stakeholder paradigm presented in this chapter has three objectives (Walesh, 1989, 1993, 1999). They are:

- The first objective is to demonstrate to the stakeholders that the public works professionals are aware of the problems, at least in a general sense; want to learn more about them; and want to seek solutions. In other words, public works professionals need to demonstrate empathy and concern. The public’s position in the early part of a planning process might be represented by the anonymous statement, “I don’t care how much you know until I know how much you care.” Sometimes the most vociferous citizens need an opportunity to vent their frustration with public works problems and the apparent inability of responsible parties to solve those problems. As stated by P. S. Hale, “We earned the public’s distrust. We’ll have to work even harder to regain their trust” (Eschenbach and Eschenbach, 1996). The interaction process must provide opportunities to express frustration, to find empathy among the public works professionals, and, hopefully, to enable frustrated individuals to become positive participants in the problem defining and solving process.
- The second objective of a stakeholder involvement program is to gather supplemental data and information pertinent to the effort. Interested citizens and officials, if informed about what they believe to be a potentially useful public works effort, are likely to contribute photographs, information on problems, ideas on solutions and other useful data and information. Similarly, but on a larger scale and in a more formal manner, various government units and agencies are likely to offer potentially useful data, reports, funding opportunities and other information if they are informed about the effort, are invited to contribute, and believe they will benefit.

- The third and final objective of stakeholder involvement is to build a base of support for rapid plan implementation. Enlightened citizens and officials, who have been informed about a public works program and have been given an opportunity to participate in it, are likely to become supporters of the program, to help interpret it for others, and to otherwise help implement it. Worthy goals are to have stakeholders exhibit pride of authorship and a sense of ownership in the public works program.

Essential to the success of a public works effort is agreement between the public and the professionals on what problems are to be mitigated or prevented. As stated by Silberman (1977), “The objectives of a public participation program should be to assure that the planners and the public have the same understanding of what the problems are and that the proposed solutions are perceived as solutions by both the planners and the public.” Concurrence on problem definition is not as simple as it may seem. For example, basement flooding in a CSS might be viewed as “the problem” by the public. In contrast, public works personnel might view such flooding as the “symptom” of the “real problem,” namely, an inadequately sized CSS or localized constrictions in the system.

## **Examples of Stakeholder Involvement Techniques**

### ***Skokie and Wilmette Approaches***

Skokie and Wilmette used, and continue to use, an effective mix of stakeholder involvement programs, events and supporting devices. Some of their strategies and tactics may be of value to other communities.

Both communities used the strategy of starting the stakeholder involvement effort at the beginning of the street storage projects, that is, when the projects were in the concept stage. Second, the stakeholder involvement process was and is being continued throughout the projects. A third shared strategy is that both communities used a variety of communication tactics.

Stakeholder involvement tactics used or being used in Skokie and Wilmette include:

- Articles in the community’s newsletter—“Newskokie” in Skokie and the “Communicator” in Wilmette.
- Cable television programs.
- Surveys of residents. Wilmette had an excellent response on its survey of residents in the CSS.
- Letters to residents.

- Public meetings which were usually held at the Village Hall. In a spirit of outreach, Wilmette conducted some meetings in resident's homes.
- Use of a committee of senior personnel, such as Skokie's Flood Task Committee, to monitor and guide the engineering consultant's efforts (Walesh and Schoeffmann, 1984).
- Physical models, like an operating, table top device created under the Skokie project to illustrate surface and subsurface storage.
- Assigning one public works person to answer telephone inquiries.
- Special brochures
- Conduct of high visibility field pilot studies that included the construction of berms, so that citizens can drive over and experience them, and the temporary flooding of streets, so that citizens could observe the depth and lateral extent of ponding.
- Video taping, for subsequent informational use, construction of facilities, ponding on streets, and vehicles driving over berms (Walesh and Schoeffmann, 1984).
- Brief discussions of the evolving street storage system as part of new resident receptions. This approach was used in Wilmette.

### ***Additional Tactics***

Many and varied other tactics have been used for interacting with stakeholders. Ideas, in addition to those presented in the preceding section, are (Walesh, 1999):

- Presentations to service clubs and other community groups: Knowledgeable and influential community leaders are typically members of one or more civic organizations such as service clubs, environmental groups, and professional associations. Because of the frequency of their regular meetings—sometimes two or more times per month—these groups are often receptive to suggestions for speakers and programs. Such presentations can help to expand knowledge of and support for a water management effort.
- School programs: By educating school children about water issues, a two-fold result can be achieved. The students gain understanding and, to the extent they share what they learned with their parents, the knowledge is disseminated.
- Guided and self-guided tours: Interested individuals and groups, including

news people, can be provided with guided tours of a project area, such as a CSS. A single bus or van, preferably equipped with a public address system, should be used for a guided tour so that all participants can easily travel together and can be provided with an informative narrative between stops. Self-guided tours are also possible if a written tour guide is available. Guided and self-guided tours enhance understanding of the location and severity of wet weather problems. Well-meaning citizens often have strong opinions about environmental problems (e.g., combined sewer overflows) that they have never seen or experienced. Tours also provide an opportunity for the public works officials and their consultants to explain and show remedial and preventive measures that are under consideration in the planning program. Another benefit of guided tours is the spirit of camaraderie that typically develops and the new interpersonal relationships that often result.

- Briefings for newly-appointed or elected public officials: By being introduced to issues and being provided with basic information on proposed, on-going or completed public works projects, new public officials are more likely to be supportive (Gilbert et al, 1981). Tactics include inviting them to join advisory committees or to attend public meetings and providing them with special briefings.
- Preparation of media packages: Example contents are summaries of regulations; descriptions with photographs of problems; brief discussions, supplemented with photographs or graphics, of potential solutions; and experiences of other communities.
- Workshops: Public works officials and their consultants can conduct workshops for interested citizens and public officials. These events provide an opportunity for in-depth exploration of substantive topics such as issues, findings, alternatives, recommendations, funding, and operations.
- Electronic-based access and input: Email and websites (e.g., Tam and Murillo, 1997) offer exciting possibilities.

## **CHAPTER 7**

### **INSPECTION AND MAINTENANCE**

#### **Essentiality of Inspection and Maintenance**

The experience of Skokie and Wilmette indicate that systematic maintenance is essential to the effective functioning of a street storage system. Such a storage-oriented system will malfunction, at least locally, if inlets or flow regulators become obstructed with leaves, twigs, Styrofoam containers and other debris.

The preceding observation is also applicable to more traditional stormwater storage facilities. It is not unique to a street storage system. The outlet works of a typical stormwater detention basin should be carefully designed to minimize the potential for blockage. Nevertheless, a systematic inspection and maintenance program is usually required to further reduce the likelihood of malfunctioning to an acceptable level.

The point is that any stormwater storage system requires some sort of outlet control structure or device. Even with thoughtful design, that outlet structure or device is subject to failure without proactive inspection and maintenance.

Both Skokie and Wilmette report increased inspection and maintenance after installation of their street storage systems. Refer, for example, to the Chapter 9 summaries of interviews with personnel from these communities. Quantifying the increased inspection and maintenance effort is difficult, although Skokie personnel described the overall effort as being “doubled.” The increased effort is significant.

In considering the increased inspection and maintenance effort, the pre-system status should be considered. Skokie, for example, carried out minimal catch basin inspection and maintenance prior to construction of the street storage system. Evidence included many completely filled sumps. Wilmette inspected and maintained catch basin sumps only once every three years prior to the street storage system. These levels of inspection and maintenance are substandard because they render the sumps ineffectual in trapping solids. However, the catch basins functioned hydraulically.

Under street storage system conditions, sumps must be largely free of debris. Leaves, twigs, Styrofoam containers and other debris trapped in catch basin sumps, if allowed to accumulate too much, will begin to plug the orifices in the hanging traps. Stated

differently, catch basin sump cleaning may be viewed as hydraulically optional in the pre-street storage system mode. However, it is mandatory with the street storage system in place.

### **Inspection and Maintenance Procedures for Skokie's Street Storage System**

Recognizing the importance of system operation, Skokie commissioned the preparation of a manual (Rust, September, 1995) to guide inspection and maintenance. This manual was first prepared in June 1993, revised in November 1994 and September 1995, and was being revised again in 1999 as this manual was being written. The specific purpose of the manual is to provide Department of Public Works personnel with information needed to operate and maintain the street storage system.

Included in the manual are a synopsis of the history and function of the street storage system, detailed description of system components, and detailed inspection and maintenance procedures. This chapter draws on the detailed inspection and maintenance procedures with the idea that they may be of interest to other CSS communities contemplating a street storage system.

Inspection and maintenance procedures are arranged in the manual according to the following six categories (quoted from Rust, September, 1995, Section 3.0).

1. Underground and surface storage basins - normal operation, inspection, and trouble shooting.
2. Stormwater storage basins and dewatering pump stations - inspection and trouble shooting guide.
3. Submersible dewatering pumps - standard maintenance procedures.
4. Flow regulators and catch basins - standard operating and maintenance procedures.
5. Street berms and diverters - standard operating and maintenance procedures.
6. Street ponding areas - standard operating and maintenance procedures.

### ***Surface and Subsurface Storage and Dewatering Facilities***

Summaries of the inspection and maintenance procedures for the first three categories are presented, respectively, in Appendices C, D, and E of this manual. Referred to as trouble shooting guides (the first two) or standard procedures (the third one), these three inspection and maintenance procedures are made available in laminated card format for Department of Public Works Personnel.

## ***Flow Regulators***

Recall that two types of flow regulators are used in Skokie. They are the hanging trap, which is widely used, and the vortex (Hydro-Brake and other) regulator, which is used when the required orifice size is too small for use of the hanging trap. Flow regulator inspection and maintenance procedures, quoted from Rust (September, 1995, Section 3.4), are:

1. Catch basins with hanging trap regulators should be inspected on a minimum annual basis and maintained as required.
2. The best time for inspection is during the fall leaf season.
3. With a sounding pole, check the structure for an accumulation of grit in the catch basin. There should be no accumulation of grit within one foot of the bottom of the orifice.
4. Excessive floating material in the catch basin that reaches the orifice inlet should also be removed.
5. Clean catch basins with hanging traps, and grit or floating material accumulations, in the same manner as a normal catch basin.
6. Ponded water in the vicinity of a catch basin with a flow regulator is an indicator of a clogged orifice.
7. If a street area is flooded because of a plugged regulator, dewater the area and catch basin with a pump.
8. Clear the clogged trap by removing and replacing it, or by removing the plug in the tee and rodding. Use confined space entry procedures if a person has to enter the catch basin structure for any reason.
9. Use a similar strategy for inspection and maintenance of vortex regulators installed in catch basins. To correct a clogged condition from a vortex regulator, the entire device might have to be removed.
10. Record inspection and maintenance information on form provided.

## Street Berms

Inspection and maintenance procedures for berms, quoted from Rust (September 1995, Section 3.5), are:

1. At a minimum, the condition of the street berms should be inspected on an annual basis. Inspect bituminous areas for the following features indicating deterioration:

Rutting. A depression in the pavement parallel to the side of the street. A depth of ½ inch is slight; ½ to 1 inch is moderate; greater than 1 inch, or such to affect vehicle steering, is severe.

Raveling. Breaking of the surface with visibly loose pieces of aggregate.

Flushing. Asphalt mixture covers the aggregate on the pavement surface.

Corrugations. Ripples are visible in the pavement perpendicular to the direction of traffic.

Alligator Cracking. Pavement cracks in a wire mesh-like pattern. Slight when barely visible; moderate when some cracks exceed 1/4 inch in width; severe when the sides of cracks become fully separated.

Transverse Cracking. Cracks in the pavement perpendicular to the direction of traffic. Severity criteria the same as for alligator cracking.

Longitudinal Cracking. Cracks in the pavement parallel to the direction of traffic. Severity criteria the same as for alligator cracking.

Patched Areas. Evidence of repaired potholes, utility cuts, or other failed areas. Slight when level with the pavement with no sign of deterioration; moderate when deteriorated, but not enough to slow traffic; severe when deteriorated and deep enough to slow traffic.

2. Repair minor deteriorated areas in street berms in the same manner as a typical street area.
3. For major damage to roadway berm areas, the surface should be scarified down to the point where a stable sub-base is reached, and resurfaced to the original grade. This work would typically not be done by Village staff, but rather by an outside contractor.
4. Reference the record contract drawings to obtain the design grade characteristics of each berm area.

5. Record inspection and maintenance data on the form provided.

### ***Street Ponding Areas***

Procedures for inspection and maintenance of street ponding areas, quoted from Rust (September 1995, Section 3.6) are:

1. At a minimum, the condition of the street ponding areas should be inspected on an annual basis. Inspect bituminous areas for the following features indicating deterioration:

Rutting. A depression in the pavement parallel to the side of the street. A depth of ½ inch is slight; ½ to 1 inch is moderate; greater than 1 inch, or such to affect vehicle steering, is severe.

Raveling. Breaking of the surface with visibly loose pieces of aggregate.

Flushing. Asphalt mixture covers the aggregate on the pavement surface.

Corrugations. Ripples are visible in the pavement perpendicular to the direction of traffic.

Alligator Cracking. Pavement cracks in a wire mesh-like pattern. Slight when barely visible; moderate when some cracks exceed 1/4 inch in width; severe when the sides of cracks become fully separated.

Transverse Cracking. Cracks in the pavement perpendicular to the direction of traffic. Severity criteria the same as for alligator cracking.

Longitudinal Cracking. Cracks in the pavement parallel to the direction of traffic. Severity criteria the same as for alligator cracking.

Patched Areas. Evidence of repaired potholes, utility cuts, or other failed areas. Slight when level with the pavement with no sign of deterioration; moderate when deteriorated, but not enough to slow traffic; severe when deteriorated and deep enough to slow traffic.

2. Repair minor deteriorated areas in street ponding areas in the same manner as a typical street area.
3. For major damage to street ponding areas, the surface should be scarified down to the point where a stable sub-base is reached, and resurfaced to the original grade. This work would typically not be done by Village staff, but rather by an outside contractor.

4. Reference the design drawings to obtain the design grade characteristics of each ponding area.
5. Record inspection and maintenance data on the form provided.

### **Safety of Inspection and Maintenance Personnel**

The Skokie Department of Public Works uses a Safety Manual (Skokie, 1992) which contains procedures to be followed by Village personnel. Much of the manual's content is applicable to inspection and maintenance of the street storage system. As stated by Rust (September, 1995, Section 4.0), with respect to safety and the street storage system, "Topics of concern that should be reviewed by all workers performing maintenance procedures include: traffic control; worksite safety; confined space entry; safety equipment; and emergencies, first aid and hygiene."

wp/epastch7

## **CHAPTER 8**

### **CONSTRUCTION COSTS**

#### **Purpose**

This chapter's purpose is to provide construction cost ideas and information which might be useful to other CSS communities contemplating street storage. Accordingly, presented are the total construction costs for those systems. Also included, for both Skokie and Wilmette, are estimated construction costs if traditional solutions had been implemented. These costs are compared to the much lower costs for the street storage systems. Street storage costs are normalized and compared to normalized costs for other options. The chapter concludes with a discussion of intangible costs.

#### **Skokie Construction Costs**

As shown in Table 8-1, the total construction cost for the Skokie street storage project, which was to be completed in 1999, is projected to be \$67 million. (This is the cumulative construction costs not adjusted for inflation. As shown in Appendix G, total construction costs converted to 1999 dollars using the ENR CCI is \$78 million.) The graphical presentation in Figure 8-1 emphasizes the differences in the relative costs of berm-flow regulator installations, sewers and supplemental storage.

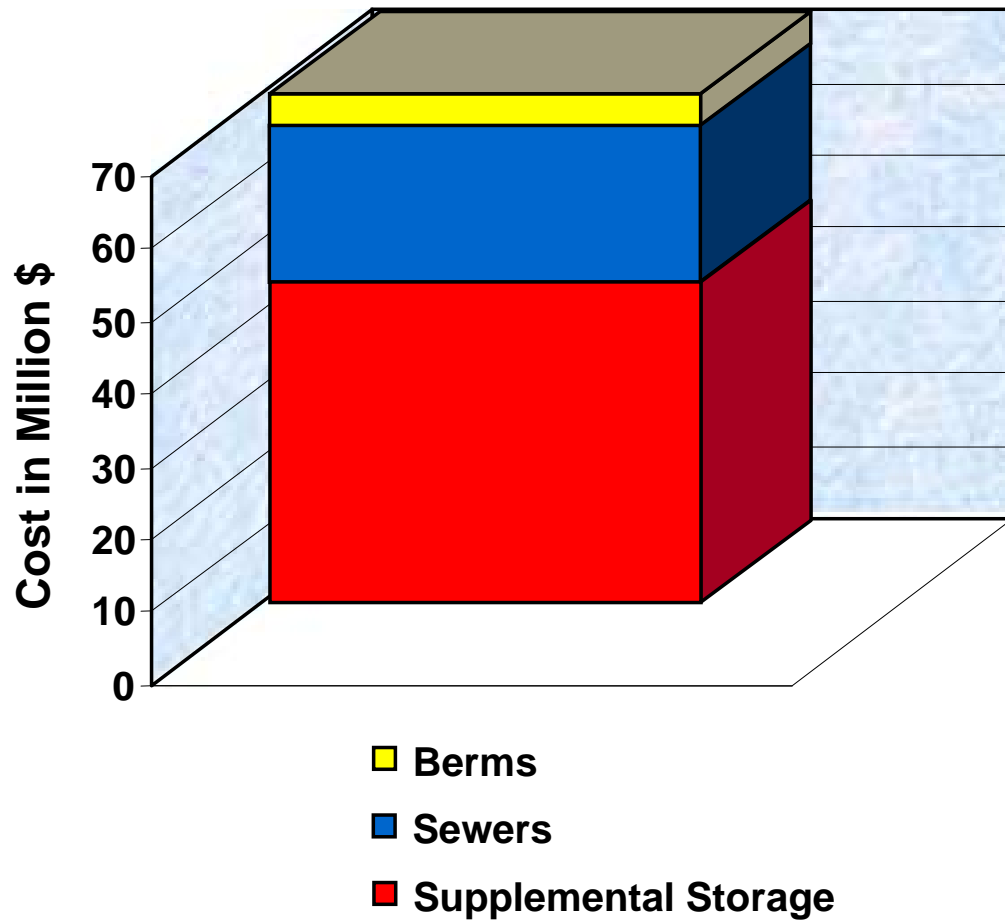
Comparison of Figure 8-1, which summarizes construction cost data, with Figure 3-35, storage location data, suggests the cost effectiveness of temporary, controlled storage of stormwater on streets. The berm-flow regulator installations in Skokie account for only nine percent of the total construction cost while providing about half of the total stormwater storage. In Wilmette, the berm-flow regulator installations account for all of the stormwater storage.

A generalization to many CSS cannot be made based largely on in-depth experience with two communities. Nevertheless, the Skokie and Wilmette case studies suggest that retrofitted storage of stormwater on streets may be very cost effective. Therefore, it should be at least considered at the outset of any urban project involving the control of stormwater runoff.

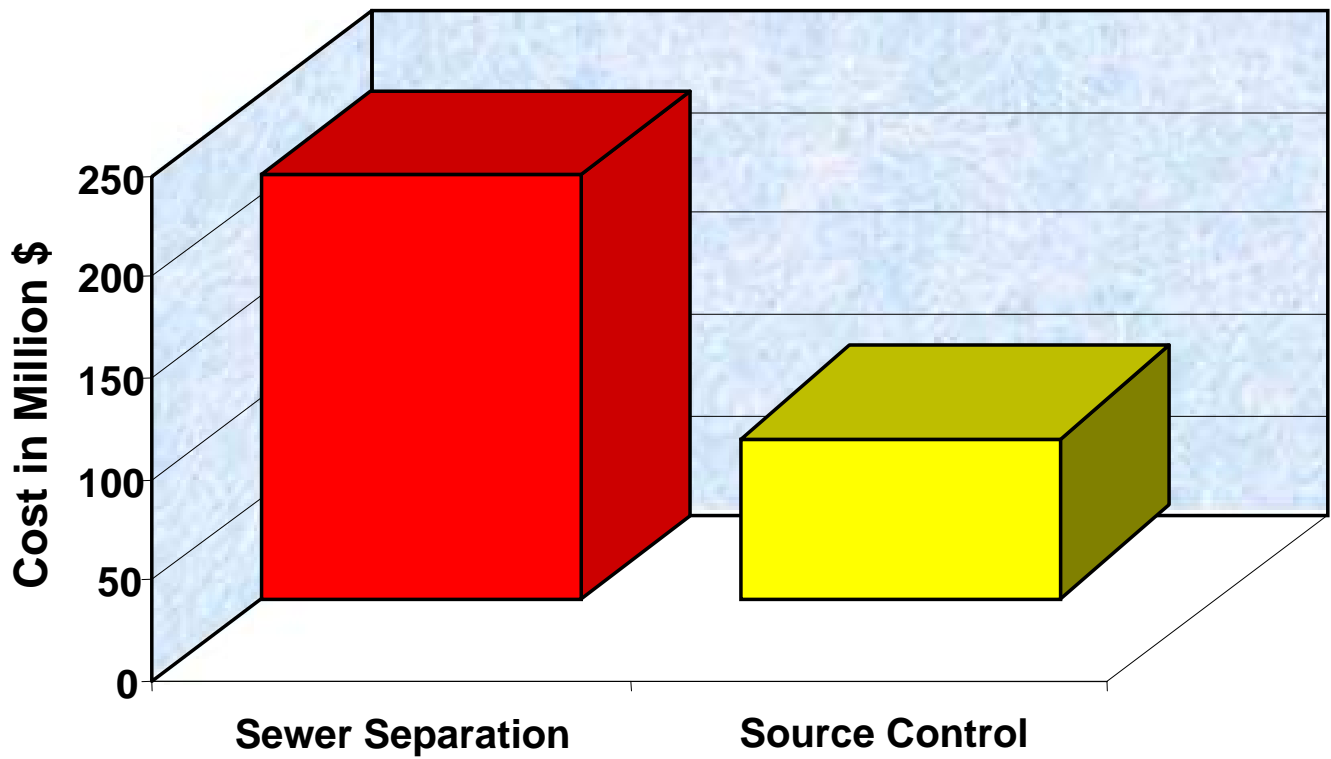
Figure 8-2 compares actual construction costs for the Skokie street storage system to the estimated cost if a traditional sewer separation project had been implemented.

**Table 8-1.** Total construction costs for the Skokie, IL street storage system (Source: Carr, 1999).

Element	Construction Cost	
	(Million \$)	% of Total
Berm-flow regulator installations	6	8.9
Storm and combined sewers	20	29.9
Supplemental storage	41	61.2
Total:	67	100.0



**Figure 8-1.** Distribution of construction costs for the Skokie street storage system showing the relatively small cost of the berm-flow regulator installations (Source: Carr, 1999).



**Figure 8-2.** Construction costs for Skokie's street storage system are about one-third the estimated cost of sewer separation (Source: Carr, 1999).

These costs are adjusted to account for inflation during the Skokie construction period. As noted, the projected construction cost of the Skokie street storage system, when expressed in 1999 dollars as developed in Appendix G, is \$78 million. As explained in Chapter 2, sewer separation costs, expressed in 1999 dollars, were estimated to be \$203 million. Therefore, the street storage system cost was about 38% of sewer separation. Skokie achieved a major construction cost saving by using the street storage system approach.

### **Wilmette Construction Costs**

The projected total construction cost for the Wilmette street storage system, with three of five phases already constructed as of early 1999, is \$35,169,000. As explained in Chapter 3, this system will eventually include about 250 berm-flow regulator installations, essentially all of which have been constructed, and tunneled and conventionally constructed relief and storm sewers.

For cost comparison purposes, a 1991 facilities plan examined sewer separation and relief combined sewer options (SEC Donohue, 1992, p. 5). Relief combined sewers were recommended at an estimated construction cost then of \$65 million. The 1999 cost would be \$81 million using the ENR CCI. Therefore, the projected construction cost of Wilmette's street storage system is about 43% the cost of the next best identified option.

### **Unit Costs**

One way to compare the costs of street storage to more traditional solutions of CSS problems is to normalize the costs, that is, develop unit construction costs. Examples of ways construction costs can be expressed on a unit basis are cost per acre, cost per person, and cost per building. While normalization of costs helps with cost comparisons, it does not reflect any economies of scale which may occur in the design or construction process. For example, construction costs are likely to be less per unit area if one contract is let for a large area than if two or more contracts are let.

### ***Skokie and Wilmette Unit Costs***

Table 8-2 presents various unit construction costs for the Skokie and Wilmette street storage systems. As a point of reference, AMSA (1994, p. 19) reports the following unit costs for sewer separation:

- Range: \$15,000 - \$176,000/acre
- Median: \$21,000

According to AMSA, these costs are based on CSO work completed as of about 1994.

**Table 8-2.** Unit construction costs for the Skokie and Wilmette street storage systems.

Item	Skokie	Wilmette
Total Projected Construction Cost (million \$)	78 <sup>1</sup>	35
Area (square miles)	8.6	2.0
Construction Cost per Acre (\$/acre)	14,200	27,300
Population in the CSS	60,000	11,300
Construction Cost per Person (\$/person)	1,300	3,100
Number of Single Family Residences	20,000	- - -
Construction Cost per Single Family Residence (\$/residence)	3,900	- - -
Number of Buildings	- - -	3,500
Construction Cost per Building (\$/building)	- - -	10,000

1) Adjusted to 1999 using the ENR CCI.

Adjusting the unit costs to 1999, using the ENR CCI, yields:

- Range: \$16,600 - \$195,000/acre
- Median: 23,300

The Skokie and Wilmette street storage unit costs of, respectively, \$14,200/acre and \$27,300/acre are at the low end of the AMSA range. The Skokie unit cost is much less than the AMSA median and the Wilmette unit cost is slightly above the AMSA median.

### ***Discussion of Unit Costs***

The preceding street storage system unit costs must be used cautiously. They are based on construction experience in only two communities. The two communities are similar in some ways. For example, flat street grades, the same climate and approximately equivalent performance criteria such as the 10-year recurrence interval design storm.

However, significant differences occur between the two communities and those differences may affect unit costs. For example, while both street storage systems include berms and relief sewers, Skokie's also includes subsurface storage.

Although both communities make intensive use of berms, many of Wilmette's are on the highly valued brick streets and required very labor-intensive construction. Furthermore, most of the required catch basins and combined sewer manholes already existed in Skokie but had to be constructed in Wilmette, further adding to costs.

Having presented the previous caveat and with it in mind, this case study strongly suggests that street storage, where physically feasible, is likely to be much less costly than sewer separation and relief sewers, a traditionally more common means of solving basement and other flooding. Stated differently, if basement and surface flooding is the only or principal CSS problem faced by a community, street storage should be viewed, from the outset, as a potential solution. So should separation and any other potential solution. If CSO's are a problem, with or without basement and other flooding, street storage should again be considered as an option, either alone or in combination with traditional technologies.

Omitting street storage as an option in cases like preceding, either because of lack of information about it or negative perception of it, could result in a community incurring construction costs that are unnecessarily high. The suggested question to be asked by a community and its stakeholders is: What is the most cost-effective means of achieving the agreed-upon level of performance?

## Intangible Costs

The preceding costs are tangible, that is, they are quantifiable in monetary terms. They are real costs. Other costs connected with resolving wet weather problems are intangible. They cannot be expressed in monetary terms. Nevertheless, these costs are very real. Lack of quantification does not make intangible costs less important but does mean that they are more difficult to weigh by stakeholders in the comprehensive decision-making process increasingly used in public works projects.

Stakeholders should identify and weigh all possible intangible costs associated with any alternative. Examples of intangible costs that might be associated with one or more potential solutions to CSS problems are:

- Noise, dust and other disruption during construction.
- Construction outside of the public right-of-way, that is, on private property.
- Loss of trees and the resulting aesthetic impact.
- Interference with or adverse re-routing of vehicular traffic after construction. This could be the case with improperly designed berms.
- Few, if any, options for future physical adjustments.

Consider an example, recognizing that generalizations are problematic. Compare the intangible costs of a sewer separation approach to a street storage system. Sewer separation will probably result in much more noise, dust and other disruptions than street storage. For example, separation is likely to involve opening up a street over the length of many blocks. In contrast, street storage is constructed at discrete locations. Sewer separation may require construction or reconstruction of building laterals outside of the public right-of-way. Street storage construction is typically and readily confined to the right-of-way. Separate sewers offer little opportunity for future, low cost adjustments. In contrast, flow regulator changes and even berm modifications are easily accomplished.

## **CHAPTER 9**

### **PERFORMANCE OF STREET STORAGE SYSTEMS**

#### **Performance: The Ultimate Test**

The proof of a public works structure, facility or system is “in the doing.” Does it perform? Elected and appointed officials in CSS communities are much more likely to consider a new process or technology if it has been proven in other similar communities. Favorable performance will be even more highly valued if it is reported by or originates with other public works officials.

This chapter documents available information on the performance (not projected performance as has been done with computer modelling) of the street storage system approach to mitigating basement and other flooding problems caused by CSS surcharging. Most of the performance information is drawn from up to 15 years of experience with the Skokie and Wilmette, IL systems. Supplemental performance information is presented from other communities that have applied, usually on a smaller scale, street storage technology.

#### **Broad Interpretation of Performance**

The word “performance” is broadly interpreted in the chapter as it should be given the realities of the public works field. A public works structure, facility or system must meet many criteria to be acceptable, especially if the structure, facility or system embodies a fundamentally new approach.

Clearly, the street storage system should perform in a functional sense. That is, it should substantially mitigate basement and other flooding caused by surcharged combined sewers. A street storage system may also be expected, as was the case in Wilmette, to reduce peak flows to the entity that operates an interceptor sewers system and wastewater treatment plants. Another possible performance test of a street storage system is its reduction in the frequency and volume of CSOs. Other likely important performance factors are:

- Economic feasibility, that is, do the benefits warrant the costs?
- Financial feasibility, that is, can the system be financed?

- Public acceptance
- Economic and financial impact on the community.
- Likelihood of generating claims or prompting legal actions.
- Impact on the effective operation of emergency and other vehicles.
- Feasibility and cost of operation and maintenance.
- Acceptance by local, regional, state and federal government agencies having a stake in the system.

In searching for ideas on ways to evaluate performance of street storage in CSS, reference was made to a summary of a series of five regional, AMSA-sponsored workshops on the theme of CSO performance measures (AMSA and Limno-Tech, 1996). As is often the case with these events and the resulting documentation, the summary report is totally devoted to the CSO problem. No mention is made of basement flooding in CSSs, solutions to that problem, or ways of evaluating the performance of implemented measures.

### **Means of Assessing Performance**

Unlike a controlled laboratory test of a small prototype of a new device, testing of a new large scale public works system is not typically carried out with intensive data collection. Street storage and related storage of stormwater is such a large scale public works system.

Accordingly, varied, qualitative and semi-quantitative means must be used to evaluate the performance of the street storage system. Means of evaluation reported in this chapter are:

- Interviews with Skokie, IL officials
- Interviews with Wilmette, IL officials
- Rainfall event incidents
- Study of economic and financial impacts

## **Summary of Interviews With Skokie, IL Officials**

### ***Participants***

Five Village of Skokie officials kindly agreed to be interviewed on December 14, 1998 as part of the EPA project. Interviewees were:

- Ms. Jacqueline Gorell, Mayor
- Mr. Albert J. Rigoni, Village Manager
- Mr. Dennis York, Director of Public Works (DPW)
- Mr. Eddy Nakai, Village Engineer
- Mr. Frank Didier, Superintendent, Water and Sewer Division

Interviewees may be contacted through:

Village Hall  
5127 Oakton Street  
Skokie, IL 60077  
Tel: 847-673-0500

### ***Process***

Stuart G. Walesh, Consultant, and Robert W. Carr of Earth Tech conducted two interviews. The first involved Mayor Gorell and Manager Rigoni. The second interview included DPW York, Engineer Nakai, and Superintendent Didier.

The objective of the comprehensive interviews was to obtain first hand ideas and information on many aspects of the community's street storage system. Because four of the five interviewees have been Skokie employees (A. Rigoni, E. Nakai and F. Didier) or an elected official (J. Gorell) throughout the life of the project, the interviews proved to be very fruitful. Value was added to the interview process by the participation of DPW York who had been employed by Skokie for only several years and, therefore, offered a fresh perspective and an objective review.

A list of questions was prepared by the interviewers prior to the interviews to facilitate a thorough, wide-ranging discussion. The list was not given to the interviewees but was used by the interviewers as an aid during the interviews. The questions are included as Appendix A.

Interviewees were encouraged to be open and frank. As suggested by the wording of most of the questions in Appendix A, both positive and negative views were sought in the hope of extracting ideas and information that would be useful to representatives of other communities contemplating street and related storage of stormwater.

### ***Results***

Partly as a result of the prepared questions and the use of open-ended inquiries, the interviewees were generous, frank and informative with their comments. Key ideas and information obtained or verified during the interviews are presented below.

***Financing:***

- Bonding is the dominant means of financing, usually without referenda. Some low interest loans have been obtained under the State Revolving Fund program through the State of Illinois as described in Chapter 5.
- There have been no large increases in taxes partly as a result of the phased construction of the system.
- On-going capital expenditures for system construction have been accepted partly because of the system's success in solving problems and partly because of the stability of the Board of Trustees and Skokie staff and citizen confidence in the Board and staff.

***Effectiveness of the System in Mitigating Basement Flooding:***

- Mayor Gorell: "Ultimately it makes your life easier... worth time, effort and money."
- Street storage is generally viewed as not a perfect solution. However, there are no perfect solutions to stormwater and wet weather problems given the random, episodic nature of meteorological events.
- A serious storm might generate 60 telephone calls from residents and property owners. In some cases, reported basement flooding may be caused by seepage of infiltrated stormwater through basement floors and wall—not necessarily back up of combined sewage.
- They "would do it again" according to Mayor Gorell and Manager Rigoni.
- DPW York, noting that the Skokie approach retrofits stormwater storage into the system, stated that the project "makes good use of what is there."
- One measure of the effectiveness of the street storage system is that news media no longer come to Skokie when heavy rainstorms occur.

- Some building owners have installed their own systems, such as standpipes in basement floor drains or overhead sewers as a backup system. Such building owner actions tend to be prompted by major rainfall events—such as the August, 1989 storm—in the interest of providing an “insurance policy.” There is concern with such actions, even though on private property, because they may be implemented without adequate knowledge and result in serious structural damage and risk to occupants. For example, as a result of standpipe installation, excessive hydrostatic pressure may build-up under basement floors and against basement walls. The floor may be raised and/or the walls collapse inward.

***Public Education and Involvement:***

- Although a major public education effort was mounted early in the project to explain the function and benefit of the street storage system, on-going public education is needed.
- On-going public education mechanisms used in Skokie include letters to citizens, cable television, and “Newskokie,” the Village’s newsletter (e.g., “Board Report” section, map of proposed street storage projects).

***Litigation:***

- There has been no litigation as a result of the street storage system.

***Claims:***

- One or two claims have been made to the Village.
- In one case, the owner of an automobile requested reimbursement for alleged water damage to his/her parked vehicle. The community denied the claim and referred the individual to their automobile insurance carrier.

***Operation of Emergency Vehicles:***

- There have been no complaints from any member of departments that use emergency vehicles (e.g., fire, police).
- There has been no damage to emergency vehicles as a result of driving over berms.

***Operation of Motor Vehicles:***

- There have been no claims for damage to vehicles as a result of driving over berms.
- No accidents are known to have been caused by ice or water directly related to the street storage system.

***Operation and Maintenance (O&M):***

- Much more O&M is needed for effective operation of the street storage system than was practiced prior to construction of the system.
- Although complete statistics are not available to quantify the increased O&M, the overall effort is described as having been doubled. One index is a doubling of O&M personnel (from two to four) and an addition of a second Vac All. Another way to portray the increased O&M effort is to note that, as a result of the street storage system, Village personnel have progressed from cleaning about 3000 catch basins to cleaning and maintaining approximately 10,000 structures (i.e., catch basins, inlets, berms and storage facilities).
- About one-half of the approximately 3100 catch basins are cleaned each year during the March through November period.
- One reason for more maintenance is a reduction in flushing action characteristic of CSS's and a corresponding increase in settling and accumulation of solids in inlets, catch basins, and pipes connecting inlets to catch basins. That is, the intentional, widespread introduction of street and related stormwater storage reduces stormwater flow rates into and through inlets, catch basins, connecting pipes and combined sewers. Thus the flow reduction, which is highly desirable for mitigating basement flooding and possibly CSO's, appears to be undesirable from the perspective of reducing self cleaning of the CSS.
- Catch basin sumps, which were not systematically cleaned prior to implementation of the street storage project, are cleaned now because catch basins are an even more essential part of the system.
- A manual is being prepared to increase the effectiveness of O&M.

- The existence of only four pumping facilities in the entire system facilitates O&M. Note: With the preceding exception, and as explained in Chapter 3, the street storage system operates solely by gravity.
- When plugging occurs, hanging trap flow regulators are much easier to rectify than vortex regulators. If any difficulty is encountered in removing debris from a hanging trap, the inexpensive device is simply broken off after which the catch basin drains and a new hanging trap is inserted. A tee, on which the two ends of the handle have been bent 90°, is used in an upside down fashion to reach into the catch basin beneath the water level, “grab” the hanging trap and pull up on it to break it off.
- A problem peculiar to vortex regulators is that sticks tend to bridge across the openings which, in turn, accumulates other debris. The initial bridging of vortex regulator openings probably occurs because the openings are not always submerged. In contrast, orifices on hanging trap regulators are always submerged by at least a few inches of water and, therefore, are less likely to be plugged by buoyant debris.
- Newer model vortex regulators have two gaskets on the cylindrical portion which inserts into the exit pipe from the catch basin. This has proven to be better than the earlier model, which had one gasket. Two gaskets are preferable because the regulator fits tighter and is less likely to fall out.
- Because of the superior O&M performance of hanging trap flow regulators, the Village would prefer to use more of them and less vortex regulators. This would be feasible if the minimum orifice diameter for hanging traps could be reduced to one inch.
- Hanging trap resistance to plugging might be improved further and/or smaller diameter orifices might be permissible by fitting the orifice end with a “bubble” or hemispherically shaped screen or grate.
- Plugging of regulators during any storm is relatively rare. For example, only five to ten of the approximately 3000 regulators will experience blockage in a runoff event.
- A positive O&M feature of the street storage system, with emphasis on continuous improvement in system operation, is the ability to make low cost, physical adjustments to the system. Examples of such adjustments, which can be motivated by observation of the system, are changing flow regulator sizes and modifying, adding or removing berms. Low cost system adjustments or “tweaking” may lead to higher levels of protection.
- Because the street storage system has so many components distributed over a large area (8.6 square miles), a user-friendly mapping system is very desirable.

For example, one approach would be interactive computer-based maps that would enable the user to easily obtain information about any component (e.g., the type and size of a particular flow regulator and the last time its catch basin was cleaned) and to readily update the data base (e.g., document the cleaning of a below-street tank).

***Monitoring:***

- Occasional, focused monitoring of parameters such as rainfall intensity, and dry and wet weather discharge in combined sewers, is very useful. It has, for example, revealed great spatial rainfall variability over the 8.6 square mile Village of Skokie.
- Monitoring of stormwater levels in subsurface tanks, which has not been done, is now desired. The principal interest is in determining if optimum use is being made of available tank capacities.
- If a system similar to Skokie's were to be planned, designed and constructed "from scratch," consideration should be given to incorporating permanent monitoring devices. An example of such a device would be pressure sensors in the floors of tanks or other device to monitor the depth of stored water. Another example would be permanent flow monitors in selected sewers.

***Downspout Disconnection:***

- Refer to Chapter 5 for a description of Skokie's early 1980's community-wide downspout disconnection program.
- This measure helps the public understand the functioning—and malfunctioning—of combined sewer systems when receiving high rates of stormwater runoff. That is, more residents recognize the cause and effect relationship between excessive rates of stormwater runoff and basement flooding.
- A mandatory downspout disconnection program should include an appeal process. Some properties have special physical circumstances precluding surface discharge of downspouts. For example, discharged stormwater may flow onto neighboring properties.

- Skokie was too lenient with bringing business and commercial properties into compliance with the community's downspout disconnection program. This was done, in part, because of the larger cost of disconnecting downspouts within some business and commercial buildings.

***Pavement Deterioration:***

- There is no evidence of accelerated deterioration of asphalt or concrete pavement as a result of the presence of the berms or the temporary ponding of stormwater on the street. As noted in Chapter 3, street storage of stormwater has occurred since 1985 in the Howard Street District, the first district in which the street storage system was implemented.

***Icing of Streets When Rainfall or Snowmelt Occurs During Freezing Temperatures:***

- This is not a problem provided the system is maintained, that is, obstructions do not prevent or greatly restrict stormwater flow into inlets.
- Because it generates water slowly, snowmelt is not a problem.
- Breaks in water mains during winter have occasionally caused freezing conditions.
- If an inlet or catch basin blockage exists during freezing conditions, a solution is to dump a mixture of hot water and snow melting compound and "rod it" with a jet truck.

***Interaction With Other Government Entities:***

- The Illinois Environmental protection Agency (IEPA), after some discussion and deliberation, decided to support the Skokie street storage system by providing low interest loans under the state's revolving fund program. Refer to Chapter 5 for details.
- The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) is a strong supporter of the Skokie project. One reason for MWRDGC support is that the street storage type systems resolve the basement flooding problem that remains after implementation of the Tunnel and Reservoir Plan (TARP). Control of CSO's to protect surface water quality is TARP's primary purpose and, as a result, there is a major residual basement flooding problem.
- The Illinois Department of Transportation (IDOT) and Cook County, in contrast with the preceding agencies, have not been supportive of the street storage system. Their concern should be viewed in the context of these agencies' roadway responsibilities and potential problems resulting from ponding of water

on arterials under their jurisdiction.

## **Summary of Interviews With Wilmette, IL Officials**

### ***Participants***

Three Village of Wilmette officials kindly agreed to be interviewed. Interviewees were:

- Mr. George Sullivan, Chair, Wilmette Sewer Commission
- Ms. Donna Jakubowski, Director of Public Works (DPW)
- Mr. Robert S. Lewis, Village Engineer
- Mr. Brad Enright, Sewer/Water Superintendent

Interviewees may be contacted through:

Village Hall  
1200 Wilmette Avenue  
Wilmette, IL 60091-0040  
Tel: 847-853-7627

### ***Process***

Stuart G. Walesh, Consultant interviewed Chair Sullivan by telephone on February 4, 1999. S. Walesh and Michael C. Morgan, Earth Tech interviewed DPW Jakubowski and Superintendent Enright in Wilmette on February 9, 1999. The second interview that day was with Engineer Lewis.

As with Skokie, the objective of the comprehensive interviews was to obtain first hand ideas and information on many aspects of the community's street storage system. Because three interviewees have been Wilmette employees (D. Jakubowski and B. Enright) or an elected official (G. Sullivan) throughout the life of the project, the interviews proved to be very fruitful. Engineer Lewis, who had been with the community less than a year at the time of the interview, provided fresh insight.

The previously mentioned list of questions (Appendix A) used for the earlier Skokie interviews were subsequently used for the Wilmette interviews. The list was not given to the interviewees but was used by the interviewers as an aid during the interviews.

Interviewees were encouraged to be open and frank. Both positive and negative views were sought, as suggested by the wording of most of the questions in Appendix A. The goal was to obtain ideas and information that would be useful to representatives of other communities contemplating street and related storage of stormwater.

### ***Results***

The interviewees were generous, frank and informative with their comments. Key ideas and information obtained or verified during the interviews are presented below.

***Financing:***

- Low interest loans were obtained through the State of Illinois as part of the State Revolving Loan Fund is described in Chapter 5. Wilmette applied for these loans based, in part, on learning of Skokie's success with this financing mechanism. All of the street storage project was funded in this manner.
- Sewer service charges, which are based on water use, have gradually increased to generate needed revenue. However, the rates are still low relative to similar neighboring communities

***Effectiveness of the System in Mitigating Basement Flooding:***

- Chair Sullivan: "Excellent, demonstrably better..." However, the community is waiting for a "huge rain" to further evaluate the performance of the system before proceeding with implementation of the fourth and fifth phases of the five phase program.
- Few, if any complaints, about basement flooding were received from residents of the CSS as a result of the August 1998 rainfall when about 2.75 inches fell. Many streets filled with water, as expected, and this caused some citizen concern. However, flooding was "drastically reduced" and the system "worked just great."

***Public Education and Involvement:***

- Chair Sullivan: "Get out in front in interacting with the public." The sewerage commission budgeted specifically for information and publicity.
- On-going public interaction efforts used in Wilmette include a survey of residents; assigning one person in Public Works to answer telephone inquiries; articles in the local weekly newspaper; new resident receptions; items in the "Communicator," the Village's newsletter; programs on cable TV and meetings at the Village hall and in citizen's homes.
- There was little difficulty in earning community acceptance and approval of the street storage system. This favorable result probably reflects the proactive approach of community leaders in interacting with the public.

***Litigation:***

- There has been no litigation as a result of the street storage system.
- A potential lawsuit did not materialize. In this situation a driver drove over a berm, apparently at excessive speed, and damaged the vehicle's under carriage. The initial issue, which was not pursued, was that the berms are speed control devices and, therefore, require appropriate signs and street markings. While it is true that signs and street markings are recommended by ITE (1997, pp. 17-19), Wilmette's position was that the berms are designed solely for flood control.

***Claims:***

- No claims have been made as a result of the street storage system.

***Operation of Emergency Vehicles:***

- One police car was damaged by "bottoming out" on one of the first berms constructed in the community. This was attributed to an excessive longitudinal slope on the first Wilmette berms. The vertical distance between the gutter invert and the street crown is generally much greater in Wilmette than in Skokie. That is, Wilmette streets typically have much more camber. Therefore, in order to hold the same maximum longitudinal slope in Wilmette as proved successful in Skokie, the longitudinal length of the Wilmette berms must be longer than the Skokie berms. Stated differently, berm longitudinal slope governs design, not berm longitudinal length. The problem with the initial Wilmette berms was rectified by altering them.
- There have been no subsequent problems with emergency vehicles.

***Operation of Motor Vehicles:***

- There has been no unfavorable rerouting of vehicular traffic onto side streets. However, berms are not generally located on high volume streets.
- No accidents are known to have been caused by ice or water directly related to the street storage system. Icing has not occurred.
- Berms function as speed humps and favorably reduce speeds on some streets. The berms do not impair driving when vehicles travel at speeds at or below the established speed limit.
- Parking patterns have been slightly altered by berms in that drivers tend to park on or downstream of berms. Recall, as explained in Chapter 3 in the section "Wilmette Performance Criteria," that street ponding depths for the design storm are limited to a maximum of six inches on the street crown and a

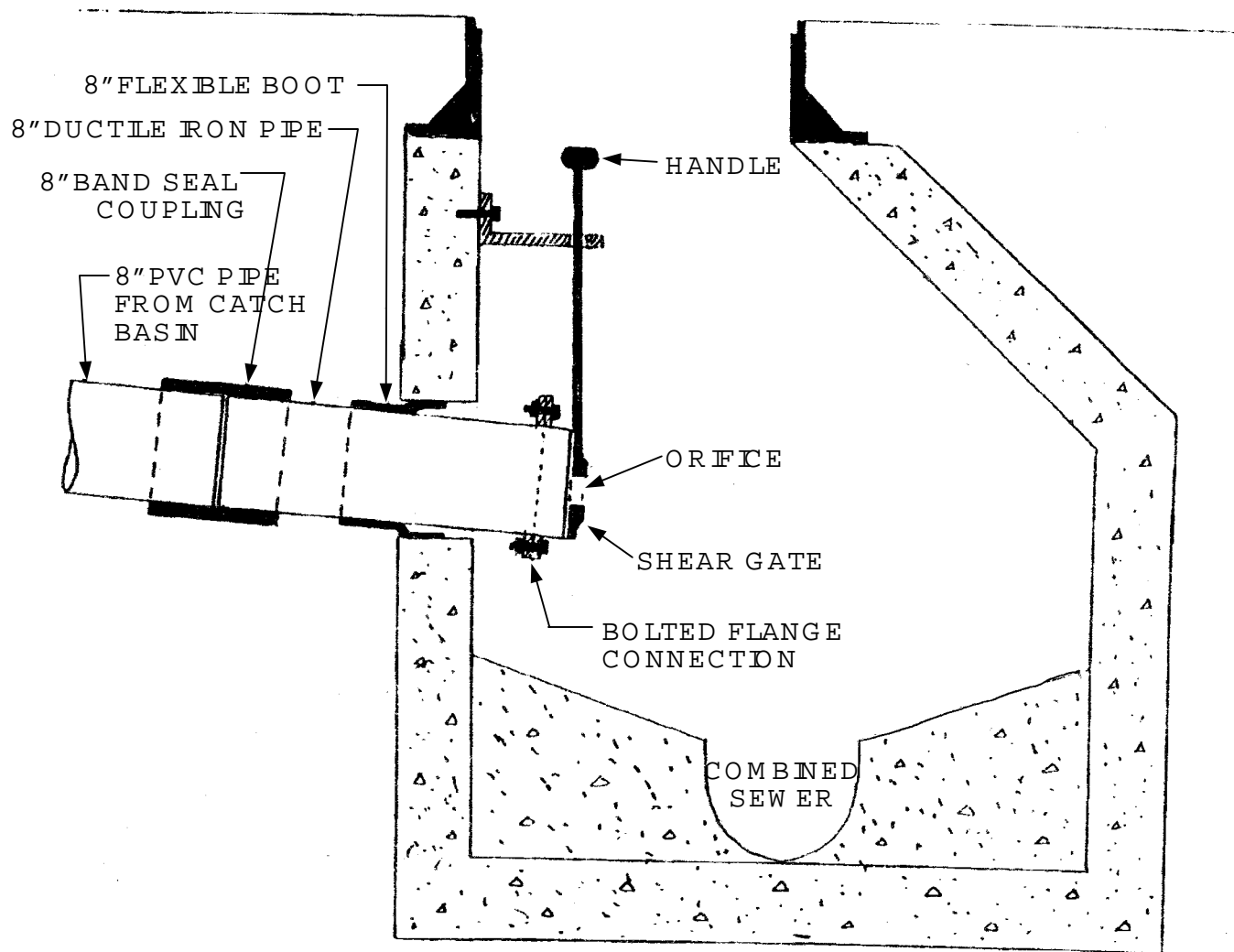
maximum of 12 inches above the gutter invert.

***Operation and Maintenance (O&M):***

- Much more O&M is needed for effective operation of the street storage system than was practiced prior to construction of the system.
- Before the street storage system, catch basin sumps were cleaned about once every three years. Now they are cleaned annually. Some sumps are probably too shallow.
- If precipitation lasts more than a couple of hours, crews usually are called out to remove blockage of catch basin grates which is typically caused by leaves. Crews drive the streets after most rainfalls.
- Berms have not interfered with snow plowing and street sweeping operations.
- Some flow regulators have become totally or partially plugged. Causes include shallow catch basin sumps and leaves being raked into catch basins by area residents. A negative result is stormwater being ponded on streets until the blockage is removed by maintenance personnel. This problem was resolved with a two step modification. Visualize an inlet-catch basin structure at the curb line connected by a pipe to a manhole on the combined sewer. The first step in the modification was to remove the hanging trap from the catch basin end of the connecting pipe. The second step, as shown in Figure 9-1, was to add a shear gate to the outfall end of the connecting pipe, that is, in the manhole on the combined sewer. The shear gate is normally kept in the closed position but contains an orifice sized to provide the allowable maximum flow of stormwater into the combined sewer. If the orifice becomes blocked, the handle mounted above it is used to open the shear gate and release the debris.

***Downspout Disconnection:***

- Some property owners objected to the effort and cost of downspout disconnection.



**Figure 9-1.** Shear gate with orifice flow regulator as used in Wilmette, IL.

- Downspout disconnection helped other citizens understand the functioning—and malfunctioning—of combined sewer systems when receiving high rates of stormwater runoff. They gained more appreciation of the cause and effect relationship between stormwater runoff and basement flooding.

### ***Pavement Deterioration***

- No pavement deterioration was reported. However, the Wilmette street storage system has only been in place for several years. No streets segments on which berms are located have been resurfaced since the berms were constructed.

### ***Icing of Streets When Rainfall or Snowmelt Occurs During Freezing Temperatures:***

- No problems have occurred.

### ***Interaction With Other Government Entities:***

- The IEPA supported the Wilmette street storage system by providing low interest loans under the state's revolving fund program.
- The MWRDGC is a strong supporter of the Wilmette project. According, to Chair Sullivan, the MWRDGC "thinks it's wonderful."

### **Rainfall - Flooding Incidents**

#### ***Typical Limited Data***

Neither Skokie nor Wilmette have kept systematic records of rainfall event characteristics (e.g., depth, duration, spatial variation, intensity, recurrence interval) or basement flooding characteristics (e.g., number of buildings affected, location). This is not unusual. Communities typically have neither the high priority need nor the equipment and personnel means to obtain and analyze such data on an essentially continuous basis over an extended period of time (e.g., years).

Instead, the rainfall event - flooding database in most communities is sporadic. It tends to focus on major rainfall events because they are more likely to cause problems. Flooding incident data is typically derived from citizen complaints and is limited in detail. Under favorable circumstances, such information consists of the number of complaints received and the corresponding location. Under less favorable circumstances, only anecdotal information is available.

In spite of the typical paucity of rainfall event - flooding data, some value can be derived from it in terms of assessing the performance of the system. The purpose of this

section is to present and interpret some of the limited rainfall event and flooding data that are available for the case study communities.

### ***June 20 - 21, 1987 Rainfall - Flooding Event in Skokie***

This event occurred during the special HSSD post-construction monitoring program. Construction of the HSSD street storage system was completed in April 1987. The monitoring program was conducted within the 1255 acre HSSD from June through September 1987. The monitoring program's purpose was to assess the performance of the street storage system and determine causes of scattered residual flooding (Donohue, 1988, p. 1-1).

The event was determined to have a recurrence interval of 10 years on the east side community and one year on the west side (Donohue, 1988, p. 5-1).

Village officials received about 20 reports of flooding as a result of the June 1987 event. Most reported problems were in the eastern portion of the district. "Complaints included sewer backups; street ponding areas too deep and extending into yards; and basement flooding" (Donohue, 1988, p. 5-1, 5-4). At that time, approximately 4600 single family residences were in the HSSD based on proportioning the community's single family residences according to sewer district areas.

The system had performed very well based, in part, on the small number of complaints relative to the number of single family residences. Furthermore, the number of HSSD complaints with the street storage system in place was minuscule compared to the pre-street storage system flooding problems described in Chapter 2.

However, given that this storm event was within the 10-year recurrence interval design of the street storage system, a high degree of performance is expected. Causes of flooding were determined to be the intentional absence of flow regulators on some arterial streets, incorrect flow regulator sizes, improper berm construction and obstructions in existing combined sewers. Specific corrective actions were recommended (Donohue, 1988, p. 6-1).

### ***August 13 - 14, 1987 Rainfall - Flooding Event in Skokie***

Also occurring during the special four month HSSD post-construction monitoring program, this event greatly exceeded the design criteria for the street storage system. A total of 7.5 inches of rainfall fell in 11 hours over an 18 hour period. The estimated recurrence interval was 300 years (Donohue, 1988, p. 4-1). In addition to the extreme rainfall, an extreme high stage occurred on the North Shore Channel, the ultimate receiving stream for the HSSD. Backwater effects of this stage, which was four feet higher than the stage used in designing the street storage system, probably caused some of the flooding (Donohue, 1988, p. 5-4).

Given the extreme severity of the August 13-14, 1987 rainfall relative to the design conditions, the event provided an opportunity to assess the robustness of the street storage system. About 85 reports of flooding within the HSSD were received by Skokie officials. As with the June 1987 event, complaints included sewer backups, excessive street ponding and basement flooding. Conclusion: The system performed very well given that the storm greatly exceeded the design conditions.

### ***August 4, 1989 Rainfall - Flooding Event in Skokie and Wilmette, IL***

According to Skokie personnel (Rigoni, 1989), the August 4, 1989 storm generated 54 complaints from residents of the 1255 acre HSSD. Recall that approximately 4600 single family residences were in the HSSD. Therefore, flooding was reported for about one percent of the residences. The complaints appeared to be “spread across the entire HSSD without any noticeable pattern.”

For comparison purposes Wilmette which, as explained in Chapter 2 is immediately north of Skokie, experienced widespread basement flooding as a result of the same August 1989 storm. Based on a postcard survey, nearly 800 buildings, or 23% of the total in the CSS, were flooded (SEC Donohue, 1992, p. 2). About 0.63 structures per acre in Wilmette reported basement flooding.

While Skokie was progressing with its street storage system, Wilmette had not yet begun. Recall that Skokie residents reported 54 basement floodings throughout the HSSD in their CSS or about 0.04 per acre. Therefore, the density of reported flooded basements in Wilmette’s CSS, which did not yet have a street storage system, was about 16 times that of Skokie which had a street storage system in place in the HSSD. In response to Skokie’s request, Donohue & Associates “...reviewed the reported basement flooding problems... and evaluated possible causes...” (Raasch, 1989a). Contrary to the initial view that the flooding incidents lacked “any noticeable pattern,” the Donohue analysis concluded that (Raasch, 1989a):

*The largest cause of the continued flooding problems was identified as runoff from streets which do not have flow regulators to control the rate at which runoff enters the sewer system.*

The review letter goes on to explain that Skokie and Donohue had decided during the planning and design of the HSSD street storage system that “stormwater runoff on selected streets or street segments would not be controlled with flow regulators because intentional ponding was not desirable.” Streets or street segments where intentional street storage was deemed undesirable fell into three categories. They were streets or street segments:

- with high traffic volumes.

- under the jurisdiction of Cook County or IDOT, two government entities that do not allow the new street storage technology.
- on Skokie borders where street storage on the Skokie side of a street might adversely affect neighboring communities.

In addition, street storage was not applied to those few streets or street segments served by separate sanitary sewers. Other supplemental circumstances cited in the Donohue letter were the possible impact of isolated combined sewage flow from outside the HSSD, contributions of parks which were assumed in the system design to not contribute runoff, and the recognition that some downspouts had not been disconnected from the CSS.

To reiterate, the conclusion of reviewing the August 4, 1989 rainfall - flooding event was that the scattered basement flooding incidents were attributed to the absence of street storage on some streets and street segments plus other factors. Stated differently, basement flooding was not caused by a failure of the street storage technology but rather by the "failure" to apply it totally to the HSSD.

The Donohue review concluded recommending various refinements and remedial actions. The principal suggestion was to revisit the original reasons for not applying street storage to some streets and street segments and, if appropriate, add street storage.

### ***May 8, 1996 Rainfall - Flooding Event in Skokie***

This rainfall was spatially varied with the most severe rainfall segment being 2.0 inches in just over an hour at the west end of the HSSD which was an eight-year recurrence interval. Wet antecedent soil conditions prevailed, because of intermittent rainfall over the preceding two days, which increased the volume of stormwater runoff.

About 75 basement flooding calls were received from across the community with approximately two-thirds occurring in the HSSD. Recall that there are about 20,000 single family residences in Skokie. If all 75 basement flooding complaints were from single family residents, then basement flooding was reported for about 0.4% of the residences. Factors causing basement flooding included unregulated inlets on IDOT arterials, wet antecedent moisture conditions, and the fact that, as of 1996, the street storage system was still being implemented in the MSSD and the ELSSD (Carr, 1999).

### ***August 5, 1999 Rainfall - Flooding Event in Skokie***

This rainfall was of one to three hours duration, as measured at five rain gauge locations in Skokie. The event was rated as having a one to 16-year recurrence interval depending on location. The storm was most severe in the HSSD.

Of the complaints received, 72 were determined to be basement flooding caused by back-up of combined sewage through floor drains. Most were in the HSSD and MSSD.

Given the small number of complaints, the street storage system performed well in light of the severity of the storm. It exceeded the 10-year recurrence interval design criterion for the street storage system. Additional explanatory factors include those noted under the discussion of the May 8, 1996 event. They were unregulated inlets on the IDOT arterials and the on-going construction of the street storage system in the ELSSD (Carr, 1999).

### **Economic and Financial Impact on Skokie**

Fishman (1998) studied the history of Skokie's street storage project with emphasis on how it was financed (as discussed in Chapter 5) and on the financial and economic well being of the community. He notes the project was the most expensive ever undertaken by Skokie. His findings highlight another dimension of the positive performance of the street storage system in that it significantly enhanced the community's economic and financial status.

Already at the beginning of the street storage project, Skokie had earned "high credit ratings" because of excellent financial management. It was "one of only 232 municipalities in the nation with Moody's coveted Aa2 rating." Moody's refers to Moody's Investor Services, an agency that rates a community's financial health for the benefit of bond investors (Fishman, 1998, pp. 181-182). Now with the street storage project almost completely implemented, "...Skokie's credit rating has been raised another notch by Moody's..." apparently based, in part, in the success of the flood control efforts (Fishman, 1998, p. 186).

Economic benefits of the street storage system include rejuvenation of downtown businesses. Fishman (1998, p. 186) concluded that:

*Downtown Skokie, where errant water once  
drove businesses away, no longer looks  
dilapidated; instead, it now resembles the  
handsome, high-rent business districts of the  
surrounding suburbs...*

Individual homeowners have also reaped economic benefits. Anecdotal evidence from real estate agents suggests that the street storage project has added \$40,000 to the value of an average house (Fishman, 1998, p. 186). The bottom line, according to Fishman (1998, p. 178), is that "Skokie is cleaner, safer and much richer" as a result of the street storage system.

## **Potential Impact of a Street Storage System on the Frequency and Volume of Combined Sewer Overflows**

Chapter 1 of this manual explains that one of the initiatives undertaken during the preparation of this manual is an exploratory analysis of the street storage system technology on the volume and frequency of CSOs and peak flows at wastewater treatment plants. Reductions in CSO volume and frequency and wastewater treatment plant peak flows would enhance the performance of the street storage system.

The exploratory analysis is documented in Appendix F. Included are a description of the methodology, presentation of results, and conclusions. Findings of the exploratory study suggests that street storage systems have the potential to provide benefits beyond mitigating basement flooding. Street storage technology may be able to significantly reduce the volume and frequency of CSOs and peak flows at wastewater treatment plants.

## Chapter 10

### Discussion

#### **Lessons Learned: How Other Communities Might Benefit From a Street Storage System**

In keeping with the theme of this manual—possible applicability of street storage as a cost-effective solution to CSS problems in many communities—this chapter begins with a lessons learned section. The lessons flow from ideas and information presented in preceding chapters. The lessons learned section is directed primarily at elected and appointed officials in communities having CSS flooding and/or overflow problems. For convenience sake, the lessons learned are summarized here by the following six categories:

- Analysis and Design
- Regulatory Compliance and Project Financing
- Stakeholder Involvement
- Evaluating System Performance
- Operation and Maintenance

#### ***Lessons Learned About Analysis and Design***

1. ***Establish and obtain concurrence on system performance criteria*** before beginning the analysis and design process. Involve stakeholders in defining the desired level of service.
2. Initial studies of CSS problems should ***focus on finding and defining the causes***. This diagnostic step should look beyond symptoms and seek out causes. Computer modeling is likely to be needed given the complexity of the typical CSS. Failure to conduct a thorough system analysis may lead to subsequent misguided efforts targeted at solving the “wrong problem.”
3. Consider, especially at the outset of the planning and preliminary design phase, ***a wide range of potential solutions***. Do not presume that traditional, and very costly solutions, like separation, relief sewers and tunnels are necessarily needed. Several to many years elapsed while Skokie and Wilmette conducted a series of studies that contemplated only

traditional solutions to their CSS problems.

4. Adopt, at least at the beginning of the analysis and design effort, **a multipurpose posture**. Become aware of and define the causes of all CSS problems—not just CSOs or basement flooding. Thinking globally is more likely to lead to a cost effective, multipurpose project.
5. Use a **phased approach** to the concept through construction process. This optimizes technical refinements and earns stakeholder acceptance.
6. **Carefully prioritize the phases**. Consider factors such as proceeding downstream in each watershed, consistency with screening criteria (Appendix B), severity of problems, stakeholder input, and windows of opportunity.
7. In CSSs, **view streets as potential partial solutions** to flooding, CSO and other problems. Given the typical low longitudinal grades of streets in CSS, streets have significant potential storage capacity in a retrofit scenario.
8. Consider integrating the stormwater berm function and the speed hump function into **one stormwater management-speed control structure**.
9. Avoid mechanical-electrical controls. Try to develop a **simple, gravity driven stormwater storage system**.
10. Select flow regulators having a very **low probability of plugging and offering ease of maintenance**.

### ***Lessons Learned About Regulatory Compliance and Project Financing***

1. **View regulations positively**. For example, they often help support a community's eligibility claim for external funding in the form of loans and grants from regulatory agencies.
2. **Seek a comprehensive and innovative technical approach** because it is most likely to attract external funding.
3. **Explore a wide range of established funding sources** and seek ways to meet the objectives of each. Investigate state and federal agencies as sources of project grants and low interest, long term loans. Skokie, for example received external financial assistance from IEPA, IDOT and Build Illinois sources.
4. Consider seeking financial support in the form of **a site specific line item appropriation from the U.S. Congress**. Having a distinctive project helps

as does a team approach involving the community, its engineer, and state and congressional representatives.

5. **Phase the project** because this enables the community staff and their consultants to seek and leverage external financing in an optimum fashion. This approach avoids needing a massive amount of funds in a short period of time and allows “small wins” to spark new project and funding supporters.
6. Establish a **downspout disconnection program** using a combination of education and ordinance enforcement. Expect the program to reduce stormwater flow into the CSS and to increase citizen understanding of the cause and effect relationship between stormwater and CSS surcharging.
7. Create a **stormwater control ordinance**. While it won’t mitigate existing CSS problems it can prevent exacerbation of those problems.

### ***Lessons Learned About Stakeholder Involvement***

1. **Recognize that a street storage project has many and varied stakeholders.** This occurs because of the large areal extent of such a project and because of regulatory compliance needs and external funding possibilities.
2. Proactively **plan, budget for and implement a stakeholder interaction program.** Begin at the outset of the street storage program and continue through the program. Avoid a reactive position. Both Skokie and Wilmette used this proactive, continuous approach.
3. **Use a variety of communication mechanisms.** Examples are informational meetings, focus groups, surveys, newspaper and newsletter articles, television and radio programs and websites.
4. **Anticipate and respond proactively to likely initial negative reaction to intentional storing of stormwater on streets.** Note the streets often flood anyway in an uncontrolled fashion, that street storage uses highly controlled, temporary ponding and that stormwater in streets is preferred over combined sewage in basements.
5. **Expect and be prepared to proactively respond to initial negative reaction to stormwater berms.** They are likely to be incorrectly confused with speed bumps. Explain that engineered speed humps (not bumps) are widely used in urban areas throughout the U.S. and that stormwater berms cause even less driver discomfort than speed humps.

### ***Lessons Learned About Evaluating System Performance***

1. ***Think broadly when choosing criteria*** to evaluate the performance of a street storage system. In Skokie, for example, the system performed very well in reducing basement flooding. It also performed very well in that it had a favorable economic impact on the community.
2. ***Obtain input from all stakeholders***. Examples are elected and appointed officials, citizens, business people, operation and maintenance personnel, emergency vehicle operators, finance experts, and regulators.
3. ***Use the number and location of citizen complaints*** received during and after storm events, along with storm severity data, as an index of system performance. Consider doing pre- and post-project surveys.

### ***Lessons Learned About Operation and Maintenance***

1. Recognize that much ***more system wide maintenance is likely to be needed once a street storage system is installed***. Maintenance that may have been optional before the street storage system, such as catch basin cleaning, is mandatory with the street storage system in place.
2. Develop an ***operation and maintenance manual or other written guidelines*** to encourage a systematic approach.

### **Criteria for Screening the Applicability of Street Storage**

#### ***Purpose of Screening Criteria***

Based largely on ideas and information presented in this manual, a set of street storage screening criteria were created. These criteria appear as Appendix B. They are offered for possible use by municipal officials and their consultants in making a preliminary determination about the likely applicability of street storage as a solution to CSS flooding and/or overflow problems in a particular community. Also included in the screening criteria are sections for screening sanitary sewer and storm water systems. These are included, because as noted in this manual, the street storage system could be used to solve wet weather problems in sanitary sewer and stormwater systems.

Assume that application of the preliminary screening criteria suggests that street storage may be suited to a particular community, or a portion of the community. The next steps might include, as they were in Skokie, selection of a pilot area; data collection; hydrologic-hydraulic modeling, possibly including water quality modeling, with and without street storage. If street storage continues to be promising, then the effort might move to preliminary engineering, cost estimating, comparison to other options and expansion to other areas. A detailed discussion of the street storage analysis and design process is presented in Chapter 3.

### ***Qualifications of Evaluators***

Community officials, consultants or other persons responsible for applying the screening criteria included as Appendix B should be very knowledgeable about the physical aspects of the community. If they are, very little time—a matter of hours—will be needed to fill in the form which follows and assess its significance. With few exceptions, such as the short general information section, a simple and quick “check-off” format is used.

In order to appreciate why certain information is being requested, individuals involved in the screening should understand the premise, components, and benefits of street storage. For that reason, these three aspects of street storage are summarized at the beginning of the screening instrument.

### ***Interpreting the Screening Information***

Assume that the evaluator is, as suggested, knowledgeable about the physical features of the community. Further assume that the evaluator understands, as also suggested, the premise, components and benefits of a street storage system. Then the evaluator should be in a good position to judge whether or not street storage is likely to be applicable. If there is uncertainty, advice could be obtained from personnel in a community that has a street storage system. Another approach would be a request assistance from an engineering consultant experienced with street storage.

## **Chapter 11**

### **Conclusions and Recommendations**

#### **Street Storage: A New Technology for Affordable Mitigation of CSS Problems**

Street storage, as documented in this manual using a largely case study approach, is a relatively new and promising concept. Proven to be technically and cost effective in the few communities where it has been systematically applied, street storage is becoming one more technology in the array of technologies available for remedial or preventive actions in CSSs.

Unlike traditional solutions to CSS problems, street storage may provide benefits that transcend CSO control. That is, street storage has the potential to provide multiple benefits in CSS communities. The first is mitigation of basement flooding caused by surcharging of combined sewers. This potential benefit has been clearly demonstrated by years of experience in Skokie, and Wilmette, IL.

The second problem that may be mitigated by the street storage system is CSOs and excessive peak flows at WWTPs. Preliminary modeling studies conducted as part of this case study project suggest that street storage alone or in combination with traditional approaches, may cost effectively reduce the annual number and volume of overflows.

Because a street storage system targets stormwater for control, the third benefit is the potential to mitigate other stormwater related problems. Examples are inflow to sanitary sewers and stormwater flooding.

Finally, because a street storage system contains many small storage facilities, scattered throughout a system, it has the potential to manage non-point source pollution. This observation is based on the premise that suspended solids are a major component of non-point source pollution and that other potential pollutants tend to be absorbed onto or adsorbed into the solids. The numerous well-maintained sumps in a street storage system provide a means for removing solids and other pollutants in stormwater. When the street storage approach is planned early and carefully tied to water quality and health benefits, state revolving fund (low interest loan) eligibility can be obtained.

#### **Recommended Research**

Achieving the full potential of street storage for mitigation of flooding and for other purposes requires research. Presented here are recommendations, informed by this case study manual, for street storage research.

### ***Integration of Speed Humps and Street Berms***

Street berms, one component of the street storage system, are physically similar to speed humps, which have proven to be effective devices for controlling vehicular speeds on urban streets. This idea is developed in Chapter 3 in the section titled “Berms and Humps: Different Functions But Similar Form.”

While both speed bumps and street berms have been independently designed by civil engineers and both have been constructed on urban streets, they apparently have never been planned and designed in an integrated fashion to control vehicles and wet weather flow. This conclusion is based on the literature review and information search conducted for this case study. No evidence was found of traffic specialists and wet weather specialists teaming to design an integrated hump-berm system.

Several possible explanations for this absence of a connection between speed humps and street berms may be offered. First, street berms are relatively new and, therefore, there has been little opportunity for a collaboration between hump and berm designers. Second, a traditional principle of street and highway design is to remove stormwater and snowmelt as quickly as possible from and beneath the pavement surface. Reasons include vehicular safety and prevention of damage to pavements and their bases. Therefore, the thought of intentionally storing water on a street may be viewed, at least initially, as unacceptable. Recall that no incidents of risk to vehicles or damage to pavement as a result of properly designed street storage of stormwater have been reported in Skokie or Wilmette.

***Therefore, preliminary research into the technical and economic feasibility of the integrating planning and design of speed humps and street berms is recommended.*** Each component has proven to be cost-effective and that cost effectiveness might be enhanced if the two devices are part of an integrated design.

Joint application of humps for vehicle speed control and berms for stormwater control should be examined in two nodes. One is retrofitting existing urban areas where speed control and wet weather flow management are needed. Retrofitting is usually the way these two devices are typically separately implemented. The other is integrating the design of the form and function of humps and berms into new urban development to optimize traffic and stormwater management.

Envisioned are traditional looking concrete or asphalt streets in a new development which, on closer examination, are seen to include numerous berm-hump structures.

Strategically placed and configured, the berm-hump structures were planned and designed for the dual purpose of stormwater runoff vehicular speed management.

The recommended preliminary research into the integration of berms and humps should include consideration of planning and design criteria and methodologies, public agency acceptance, public acceptance, constructability, cost, and maintenance.

### ***Street Storage to Reduce CSOs and Peak Flows at WWTPs***

As noted, special hydrologic-hydraulic modeling conducted for this case study project suggests that the street storage technology may help to significantly reduce the annual number and volume of CSOs. Given the proven capability of a street storage system to cost-effectively mitigate basement flooding, the need for some communities to mitigate both basement flooding and CSOs, and the limited funds available to communities, the possibility of using the street storage technology to cost-effectively solve two or more problems warrants further study.

Consider, for example, a community where end-of-pipe storage is being considered to mitigate CSOs. Assume the community also has a basement flooding problem. A street storage system, implemented alone or in combination with reduced end-of-pipe storage, might provide the most cost-effective overall solution to the hypothetical community's two problems. ***Therefore, additional primarily modeling studies of the role of street storage in reducing CSOs and peak flows at WWTPs is recommended.*** The approach described in Appendix F is suggested, that is, select actual CSSs and use computer modeling to determine the annual frequency and volume of CSOs and the magnitude and frequency of peak flows with and without street storage systems. These modeling studies could be integrated with the modeling studies suggested under the next recommended research topic.

### ***Costs and Benefits of Street Storage Versus Traditional Approaches***

The Skokie and Wilmette case studies suggest that street storage, where physically feasible, is likely to be much less costly than sewer separation and relief sewers in solving basement and other flooding. Stated differently, if basement and surface flooding is the only or principal CSS problem faced by a community, economics indicates that street storage should be viewed, from the outset, as a potential solution. So should separation and any other potential solution. If CSOs are a problem, with or without basement and other flooding, street storage should again, because of costs, be considered as an option, either alone or in combination with traditional technologies.

Needed is a rigorous comparison of the costs and benefits of street storage, sewer separation, relief sewers, and end-of-pipe storage. While tangible and intangible costs are obviously important in such a comparison, tangible and intangible benefits also must be considered. This is because traditional CSS remedial methods tend to be

single purpose (usually reduction of CSOs), whereas street storage is likely to be multiple purpose. The lower cost of street storage coupled with more benefits may make yield a very high economic advantage. However, relevant data, information and insight are needed.

***Therefore, research into the tangible and intangible costs and benefits of street storage compared to traditional approaches is recommended.*** One approach would be to retrofit, “on paper,” street storage into one or more CSSs in which sewer separation, relief sewers, or end-of-pipe storage has already been applied. Determine tangible and intangible retrofit costs and compare to actual costs already incurred. Similarly identify tangible and intangible benefits. Draw conclusions based on the costs and benefits. Another approach would be to draw on historic tangible cost data for all types of methodologies. Normalize the costs by presenting them on a unit cost basis where the units might be acres, buildings, or persons. Again, make comparisons.

### ***Further Improvement to Hanging Traps***

Hanging traps have proven, based on years of experience in Skokie and Wilmette, IL, to be a very effective way of controlling the rate of flow from catchbasins into combined sewers. Positive attributes include low cost, very little maintenance and ease of replacement. As noted in the Chapter 9 section titled “Summary of Interviews With Skokie, IL Officials,” maintenance personnel prefer the simple, low cost hanging trap flow regulators over the much more costly vortex regulators.

More hanging trap regulators could be used if the minimum orifice diameter for hanging traps could be reduced to one inch. Furthermore, as explained in Chapter 9, this might be possible if the hanging traps were fitted with a “bubble” or hemispherically shaped screen or grill. This screen or grill would prevent debris from reaching and blocking the small orifice.

***Therefore, research leading to development of an effective, low cost screen or grill for hanging trap regulators is recommended.*** Various configurations could be performance tested in a laboratory setting. Testing should include various sizes and shapes of sumps, recognizing that sump depth and shape probably affect hanging trap performance. A promising subset could then be field tested.

The hanging trap research might be extended to include optimizing the entire catch basin. Water quality management would be the focus of this part of the research. For ideas on improving catch basins, see Grottke (1989). There may be room for improvement. Consider this conclusion based on Swiss studies (Conradin, 1989):

*...the construction and operation of catch basins is not really feasible from the economic point of view. Nor would catch basins probably*

*have much justification in the combined sewer system, for ecological reasons, when streets are cleaned frequently by the vacuum method.*

### **Street Storage as Part of New Combined Sewer Systems**

Since the 1930's and 1940's, U.S. sewage policy has embraced constructing separate, as opposed to combined, sewer systems in newly urbanizing areas (Burian et al, 1999, p. 7). Selection of this policy for new urban areas led to some major sewer separation projects in the CSS portions of U.S. communities. Examples are Minneapolis-St. Paul, MN and Hartford, CT (AMSA, 1994, p. 17).

While separate sewers have been the “system of choice” in the U.S. for several decades, which may appear to be a long time, CSSs have been used throughout western and eastern civilizations for many centuries. As an example, Burian et al (1999, p. 4) states:

*The Indus civilization, circa 3000 BC, presents one example of a sewage system ahead of its time. The dwellers of the city of Mohenjo-Daro (now part of West Pakistan) used a simple sanitary sewer system and had drains to remove stormwater from the streets. The ruins of this ancient system illustrate care taken to construct the sewers that would make the engineer of today envious. One feature of note was the use of a cunette in the storm drain to accommodate sanitary wastewater flows, while the remaining capacity of the channel was available for WWF.*

Furthermore, CSSs are being constructed today in various countries. Examples are Germany, Japan and Switzerland. Rather than continue to embrace a rigid SSS or CSS stance, there appears to be some interest in the U.S. and elsewhere to consider CSSs for certain types of new development (Burian et al., 1999, p. 11).

Interest in CSS for new development gets added impetus when the adverse water quality impact of stormwater runoff is considered. With a CSS, at least some of the stormwater would be captured and routed through treatment before release into the receiving waters. Using a portion of Elizabeth, NJ, Kaufman and Lai (1978) studied various types of sewer systems for pollution abatement and flood control purposes. Hypothetical systems studied were a conventional separate storm and sanitary sewer system; a conventional CSS; and an advanced CSS meaning that it included in-pipe storage, satellite storage, and controlled flow routing. Unlike the street storage system

described in this manual, storage meant storage of combined sewage, not stormwater. One conclusion with respect to the advanced CSS was that a “combined sewer system can be designed to discharge less pollutant than a conventional separate system in which the storm sewers discharge all urban runoff directly to water courses” (Kaufman and Lai, 1978, p. 4).

Given the apparent openness to at least considering CSSs in some types of new urban development, the street storage technology becomes even more relevant. Its potential function in new CSSs would be to reduce peak flows of stormwater into the CSS thus reducing the size and cost of the combined sewers.

***Therefore, integrating street storage into any known proposed or on-going studies of new CSS is recommended.*** If such studies are not proposed or underway, they should be.

### ***Impact of a Street Storage System on Non-Point Source Pollution***

As noted earlier in this chapter, the many well maintained sumps strategically placed around a street storage system offer the potential to remove suspended solids as well as absorbed and adsorbed potential pollutants from stormwater. This suggests the value of knowing the pollutant removal performance of street storage systems for possible multipurpose use in existing or new CSS and separate sewer systems.

***Therefore, research into the pollutant removal effectiveness of street storage systems is recommended.*** This research might include computer modeling, laboratory, and field monitoring elements.

## **Appendix A**

### **Questions Used to Prompt Discussion in Interviews of Skokie Officials**

1. Intentionally storing stormwater on streets is unusual, but, in your case, effective. How do you explain the benefits of street storage to citizens and/or elected officials? Stated differently, how do you know that street storage “works?”
2. In your view, what are the key guiding principles in dealing with the public on problems and solutions in the public works field?
3. Street and supplemental storage of stormwater seems to be a cost-effective (lowest cost) solution to basement flooding in Skokie. If you could go back to the beginning of the project (early, 1980's), would you do it again? Or would you “hold out” for a more traditional and more costlier solution?
4. When street storage of stormwater was initially proposed, concern was expressed over accelerated deterioration of pavement. What is your experience?
5. When street storage of stormwater was initially proposed, concern was expressed over dangerous icing of streets during freezing temperatures. What is your experience?
6. Are you aware of any accidents caused by standing water?
7. When street storage of stormwater was initially proposed, concern was expressed over interference with normal movement of vehicles. What is your experience?
8. When street storage of stormwater was initially proposed, concern was expressed over interference with operation of emergency vehicles (e.g., police cars, fire engines). What is your experience?

9. Are you aware of any damage to vehicles directly related to the system or its components?
10. What is the weakest “link” (e.g., hanging traps, berms, subsurface tanks, etc.) in the physical system?
11. Has the Village encountered any legal (e.g., liability) problems as a direct result of street storage?
12. Street and related storage of stormwater typically requires careful maintenance of the drainage system. Examples include keeping inlet grates clear of debris, removing sediment and other deposits from catch basin sumps, and cleaning clogged flow regulators. To what extent has increased maintenance been a financial/personnel burden?
13. How has your method of resolving basement flooding been received by regulatory/operating agencies? That is, has your approach been an advantage, disadvantage or “wash” with other governmental units?
14. How have you funded your “street storage” system? Anything special/different/unique about this means of funding vis-a-vis other public works projects?
15. Have there been any favorable or unfavorable effects on traffic flow such as excessive speed reduction and unwanted diversion of vehicles to other streets?

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# Appendix B

## Criteria For Screening Applicability Of Street Storage

Note: Before using this screening instrument, please read the section in Chapter 10 titled “Criteria for Screening the Applicability of Street Storage.” In order to appreciate why certain information is being requested, the person(s) involved in the screening should understand the premise, components, and benefits of street storage. For that reason, these three aspects of street storage are summarized here.

### PREMISE OF A STREET STORAGE SYSTEM

Temporarily store stormwater on the surface (off-street and on-street) and, as needed, below the surface close to the **source**, that is, where it falls as precipitation and **prior to its entry** into the combined, sanitary, or storm sewer system. Accept the full volume of stormwater runoff into the sewer system but **greatly reduce the peak rate of entry** of stormwater into the system.

### COMPONENTS OF A STREET STORAGE

- **Downspout disconnection** to slow down and possibly infiltrate stormwater
- **Off-street surface storage** of stormwater (conventional detention/retention) with regulated outflow
- **On-street surface storage** with regulated outflow achieved by an optimum combination of on-street berms and catchbasin flow restrictors
- **Sub-surface storage** of stormwater (tanks or oversized sewer segments beneath streets and parking lots) with regulated outlet control using restrictors

## BENEFITS OF A STREET STORAGE SYSTEM

Street storage technology has the potential, depending on the situation, to cost-effectively mitigate one or more of the following wet weather condition problems:

- **Basement flooding** caused by surcharging of combined and/or sanitary sewers
- **Overflow** of combined and/or sanitary sewers and resulting pollution of receiving waters
- **Excessive peak flow** at wastewater treatment plants
- **Nonpoint source pollution**
- **Surface flooding** caused by stormwater runoff and/or surcharging of combined or sanitary sewers.

### General Information About the Community

1. Name of community/government entity:

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2. Name and affiliation of person(s) responsible for conducting screening:

Person	Affiliation	Telephone Fax/ Email
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

3. Dates or period of screening:

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4. Population of community/government entity:

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5. Area of community/government entity:

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6. Overall longitudinal street grades (select one):

- < 0.2% (0.2 feet per 100 ft. along the street centerline)
- 0.2 < 0.5%
- 0.5 < %

Comment: \_\_\_\_\_

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***Combined Sewer System Information***

QUESTION	YES OR OFTEN	MAYBE OR SOMETIMES	NO OR RARELY	COMMENTS
Are combined sewers present in at least part of the community?				
If the answer to the first question is "no," go to the section titled "Concluding Comments" or go to the set of questions under the section titled "Sanitary Sewer System Information"  If the answer to the first question is "yes," the following questions apply only to the areas served by combined sewers.				
Are combined sewers structurally sound?				
Do basements flood because of combined sewer surcharging?				

Do streets flood because of combined sewer surcharging?				
Do combined sewers overflow into surface waters?				
Are off-street sites available for surface detention/retention of stormwater?				
Is nonpoint source pollution a concern?				
Is the wastewater treatment plant operating at or over its treatment capacity?				
Is the wastewater treatment plant operating at or over its treatment capacity?				
Has the community already decided on a solution to its combined sewer problems or is the community still "open" to alternative solutions?				

### ***Sanitary Sewer System Information***

<b>QUESTION</b>	<b>YES OR OFTEN</b>	<b>MAYBE OR SOMETIMES</b>	<b>NO OR RARELY</b>	<b>COMMENTS</b>
Is a separate sanitary sewer system present in at least part of the community?				

<p>If the answer to the first question is "no," go to the section titled "Concluding Comments" or go to the set of questions under the section titled "Stormwater System Information"</p> <p>If the answer to the first question is "yes," the following questions apply only to the areas served by sanitary sewers.</p>				
Are sanitary sewers structurally sound?				
Do basements flood because of backup or sanitary sewage?				
Do sanitary sewers overflow into surface waters?				
Is infiltration (of groundwater) into sanitary sewers a problem/cause of problems?				
Is inflow of stormwater into sanitary sewers a problem/cause of problems?				
Is the wastewater treatment plant operating at or over its treatment capacity?				
Has the community already decided on a solution to its sanitary sewer problems or is the community "open" to alternative solutions?				

### ***Stormwater System Information***

<b>QUESTION</b>	<b>YES OR OFTEN</b>	<b>MAYBE OR SOMETIMES</b>	<b>NO OR RARELY</b>	<b>COMMENTS</b>
Is a separate stormwater system present in at least part of the community?				
<p>If the answer to the first question is "no," go to the section titled "Concluding Comments."</p> <p>If the answer to the first question is "yes," the following questions apply only to the areas served by separate stormwater system.</p>				
Are the storm sewers structurally sound?				
Are residential, business and other buildings and property damaged by stormwater?				
Are off-street surface sites available for surface detention/retention of stormwater?				
Is nonpoint source pollution a concern?				
Does the community have an erosion/ sedimentation/ stormwater control ordinance?				
Does the community have a separate stormwater service fee?				

Has the community already decided on a solution to its stormwater problems or is the community “open” to alternative solutions?				
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## CONCLUDING COMMENTS

Additional ideas/concerns/questions/suggestions/etc.

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**Appendix C**

**Trouble Shooting Guide**  
**for**  
**Underground and Surface Storage Basins**  
**with**  
**Gravity Dewatering**

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**UNDERGROUND AND SURFACE STORAGE BASINS WITH GRAVITY DEWATERING  
NORMAL OPERATION, INSPECTION AND TROUBLESHOOTING GUIDE  
Skokie, Illinois**

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**NORMAL OPERATION**

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Storage structures with gravity drainage include relief sewers, underground vaults, and surface storage basins. The normal operating sequence of areas with gravity drainage during a storm event is:

- ❖ Rainfall runoff from the streets in these areas drains directly from the inlets to the underground or surface storage basins.
  - ❖ The basins provide additional stormwater runoff storage and protection from combined sewer surcharging and basement flooding.
  - ❖ The water is discharged by gravity from the storage basin to the combined sewer system. The discharge rate from the storage basin is controlled by a restrictor device at the outlet end. A check valve at the outlet pipe prevents backflow of combined sewage into the separated stormwater runoff system.
- 

**INSPECTION AND TROUBLESHOOTING**

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<b>CONDITION OBSERVED</b>	<b>POSSIBLE CAUSE</b>	<b>CORRECTIVE ACTION</b>
❖ Streets for basin area flooded	Very heavy rainfall filled storage basin.	Extremely heavy rainfall could cause ponding on major streets.
	Associated street inlets plugged.	Check for free flow of stormwater at inlets or flooded street areas. Clear street inlets.
❖ Rain stopped, streets not draining	Restrictor orifice is clogged	Check for free discharge at manhole where basin drainage re-enters combined sewer system. Open bypass valve on street for emergency drainage. Rod or flush out obstruction in orifice or discharge pipe to combined sewer. Flush out basin drainage area with city water.
	Basin has filled. Combined sewer still surcharged.	Drainage will resume when combined sewers are no longer surcharged. No action needed.
❖ Sewage odor after basins have drained	Stagnant water in basin. Check valve not working.	Check manholes with check valve. Check for and remove any debris lodged in check valve.
<u>Dry Weather Inspection and Maintenance</u>		
❖ Inspect street inlets for area basins (Annually in fall).		Clean out any debris that would inhibit drainage into basin.
❖ Inspect condition of check valve and orifice (Annually in fall).		Clear out any debris lodged in check valve or orifice plate.
❖ Exercise bypass drain valve (Annually in fall).		With valve open, inspect for accumulations of grit and sediment. Flush out any excess accumulations with city water.

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**Appendix D**

**Trouble Shooting Guide**  
**for**  
**Stormwater Storage Basins -**  
**Dewatering Pump Stations**

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**STORMWATER STORAGE BASINS - DEWATERING PUMP STATIONS**  
**INSPECTION AND TROUBLESHOOTING GUIDE**  
**Skokie, Illinois**

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CONDITION OBSERVED	POSSIBLE CAUSE	CORRECTIVE ACTION
<b>STORMWATER BASINS</b>		
<u>Rain Period - Basin Filling</u>		
❖ Streets for area basins flooded	Very heavy rainfall filled basin.	Extremely heavy rainfall could cause ponding on major streets. Secure appropriate traffic controls.
	Associated street inlets plugged.	Check for free flow of stormwater at inlets or flooded street areas. Clear street inlets.
❖ Rainfall without basins filling	Combined sewers not surcharged.	Rain not sufficient to surcharge combined sewers. Verify by checking that water level is below divider wall on siphon side of inlet structures: 8Z.1 - Area 8; 9P.0 - Area 9.
❖ Area 9 - light rain, combined sewer not surcharged, pumps running	Pumping low flow from Dempster Street.	All flow entering the north basin in Area 9 from Dempster Street must be pumped by the dewatering pumps to reach the combined sewer on Skokie Boulevard. No action needed.
<u>Rain Over - Basin Draining</u>		
❖ Rain stopped, basin not gravity draining	Restrictor orifice is clogged.	Check for free discharge at manhole where basin drainage re-enters combined sewer system: Area 8 - Structure 8P.0 (Oakton Street at Skokie Boulevard); Area 9 - Structure 9P.2 (combined gravity and pumped discharge). Dislodge clogged orifice by rodding or flushing. In Area 8, bypass valve at vault 80.4 can be opened.
	Plug valve failed closed (Area 9)	Depress RESET at control panel to clear fail. If condition remains, open plug valve using manual override. Call electrical service contractor if valve operator or panel malfunction.

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**STORMWATER STORAGE BASINS - DEWATERING PUMP STATIONS**  
**INSPECTION AND TROUBLESHOOTING GUIDE**  
Skokie, Illinois

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CONDITION OBSERVED	POSSIBLE CAUSE	CORRECTIVE ACTION
<b>STORMWATER BASINS (Continued)</b>		
<u>Basin Draining</u> (Continued)		
❖ Basin drained to gravity point, pumps won't start	Additional rain surcharged the combined sewer.	Pumps won't start if combined sewers still surcharged. Verify that water level is at top of divider walls at control structures.
	Pump Float Switch No. 6 or other controls not working.	Check float condition and levels. Manually trip floats with long pike pole. Check for other pump failure conditions noted below.
❖ Pumps operating, basin not draining	Restrictor orifice is clogged.	See above for no gravity draining.
	Pumps not pumping capacity.	See pumping guidelines below.
❖ Sewage odor after basins have drained	Stagnant water in siphon. Check valve not working.	Check manholes with check valve. Check for and remove any debris lodged in check valve. Dewater siphons by opening drain valve to remove stagnant water.
<u>Dry Weather Inspections</u>		
❖ Prevent basin drain clogging		Clear any accumulated debris from basin drains. Remove debris from perimeter of basin.

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**STORMWATER STORAGE BASINS - DEWATERING PUMP STATIONS**  
**INSPECTION AND TROUBLESHOOTING GUIDE**  
**Skokie, Illinois**

CONDITION OBSERVED	POSSIBLE CAUSE	CORRECTIVE ACTION
<b>PUMPING STATIONS</b>		
❖ Pump operating with severe noise or vibration	Pump not seated properly.	Pull pump and re-seat on guide rail system.
❖ Pumps operating but not pumping capacity	Pump impeller or volute clogged.	Pull pump and unclog.
	Pump discharge clogged.	Check first manhole for pump discharge. Remove pump and rod out or flush discharge line.
	Basin dewatering drain plugged.	Verify by low sump level but considerable water remaining in the basin to pump. Rod out or flush basin drain. Dewater with alternate pump if necessary.
<u>Panel Alarm Indicators:</u>		
❖ Pump Fail	Power failure.	Pump RESET switch must be depressed before restarting pumps in AUTOMATIC mode upon restoration of power after power failure, circuit breaker trip, or any other type of failure listed.
	Other conditions indicated by specific alarm lights:	
❖ Pump High Temperature	Low cooling oil level.	Pull pump and check cooling oil if pump repeatedly overheats.
	Debris in impeller.	Pull pump and remove debris from impeller.
❖ Pump High Moisture	Pump motor seal failed.	Pull pump and inspect stator casing for moisture. Call pump service representative if moisture is in motor housing.
❖ Low Sump Level	Low level or normal pump cutout float switch not working or hung up.	With pumps in AUTOMATIC, use a long pike pole to manipulate floats by hand to trip. Check for correct level of floats. Call electrical service contractor if pump floats have become inoperative.
❖ High Basin Level	Very heavy rainfall filled basin.	Extremely heavy rainfall could cause ponding on major streets. Secure appropriate traffic controls.
❖ Plug Valve Fail (Area 9)	Valve will not reach limit position (open or close). Debris clogging valve.	Manually open valve with override and manually start pumps to flush out debris.
	Limits of valve out of adjustment.	Refer to Limitorque valve operator manual or call electrical service contractor.

**Appendix E**

**Standard Maintenance Procedures  
for  
Submersible Dewatering Pumps -  
Stormwater Storage Basins**

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**SUBMERSIBLE DEWATERING PUMPS - STORMWATER STORAGE BASINS**  
**STANDARD MAINTENANCE PROCEDURES**  
**Skokie, Illinois**

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**EQUIPMENT CONTRACTORS**

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PUMP SUPPLIER:

Hydroaire Incorporated  
834 West Madison  
Chicago, IL 60607  
Phone: 312-738-3000  
Fax: 312-738-3226  
Project No.: AKFL 10280

ELECTRICAL PANEL INSTALLATION:

Aldridge Electric  
28572 N. Bradley Road  
Libertyville, IL 60048  
Phone: 708-680-5200  
Fax: 708-680-5298

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**PUMP LIST**

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LOCATION:	AREA 4	AREA 8	AREA 8	AREA 9
<u>ITEM</u>				
Pump Tag No.	P-4-1, 4-2	P-8-1	P-8-2	P-9-1, 9-2
Make	Flygt	Flygt	Flygt	Flygt
Model No.	CP-3085	CP-3152	CP-3102	CP-3152
Impeller No.	438	624	442	620
Impeller Size	4"	10"	6"	10"
Horsepower	2.0	14	5	14
Flow, gpm	210	2250	450	3000
Head, feet	12.0	11.5	18.5	12.0

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**SAFETY PRECAUTIONS**

1. Always lock out and tag the submersible pumping equipment before removing it from the sump for inspection or maintenance.
2. Use only the hoisting equipment recommended by the equipment manufacturer to remove the pumps from the sump.
3. Rinse the pump thoroughly with clean water before handling or inspecting the pump.
4. The pumps are designed to be removed from the sumps without anyone entering.
5. If for any reason it becomes necessary to enter the sump, follow proper confined space entry procedures.
6. If checking or changing the oil, hold a rag over the oil casing screw when removing it.

**SUBMERSIBLE DEWATERING PUMPS - STORMWATER STORAGE BASINS  
STANDARD MAINTENANCE PROCEDURES (Continued)  
Skokie, Illinois**

**MAINTENANCE PROCEDURES**

<u>DESCRIPTION</u>	<u>FREQUENCY</u>	<u>LUBRICANT/PARTS</u>	<u>REMARKS</u>
1. Inspect impeller and volute	12 months		Replace severely worn impellers. Check for clogging and remove debris if needed. Have service representative adjust impeller clearance if needed.
2. Inspect motor seal for proper oil level and possible contamination. Replace oil containing water or if cream-like.	12 months	Cooling Oil	Use Mobil Whiterex 309 or ordinary SAE 10W-30.
3. Inspect the stator casing.	24 months	Seal	If oil or water is in the stator housing call the Flygt representative.
4. Complete pump overhaul	5 years		Interval recommended by manufacturer for overhaul. Best performed for Skokie during winter dry weather months.

**STATION INSPECTIONS**

1. Inspect stations weekly during wet weather months or more frequently during heavy rain events. Note general condition of structure, surrounding ground or grass area, control panel, and signs of forced entry or vandalism.
2. Record the pump hour meter readings and electric meter readings.
3. Observe the electrical panel for any alarm conditions: High water level, low water level, high temperature fail, seal leak. Record alarm occurrences on station inspection form.
4. Check bottom of sump for debris buildup. Remove excess debris as required.
5. Alternate the pump sequence with the LEAD/LAG switches to obtain equal running time for the pumps at Area 9.

Notes:

- a. The pump station for Area 8 should always have Pump No. 1 as the lead pump and Pump No. 2 as the lag pump. On this station, the pumps will always have unequal run times.
- b. When the pumps at the Area 4 station are set in the ALTERNATE position on the control panel, they will automatically alternate in sequence.

**REFERENCE**

Flygt Model CP Submersible Pump Installation and Maintenance Manual (provided with each pump).  
Village of Skokie Operation and Maintenance Manual, Stormwater Runoff Control Facilities.

**SUBMERSIBLE DEWATERING PUMPS - STORMWATER STORAGE BASINS  
INSPECTION FORM  
Skokie, Illinois**

Date	Hour Meters		Electric Meter	Comments
	Pump 1	Pump 2		

PUMP STATION AREA:   \_\_\_\_\_ AREA 4 (OAKTON AND FLORAL)  
                                   \_\_\_\_\_ AREA 8 (GABION POND)  
                                   \_\_\_\_\_ AREA 9 (EVANSTON GOLF CLUB)

**Appendix F**

**Exploratory Analysis  
of the  
Impact of a Street Storage System  
on the  
Frequency and Volume  
of  
Combined Sewer Overflows**

Note:

This analysis and its documentation was prepared by Robert W. Carr, PE and Michael C. Morgan, PE of Earth Tech.

## Introduction

Street storage has been proven to substantially reduce basement flooding in various communities.

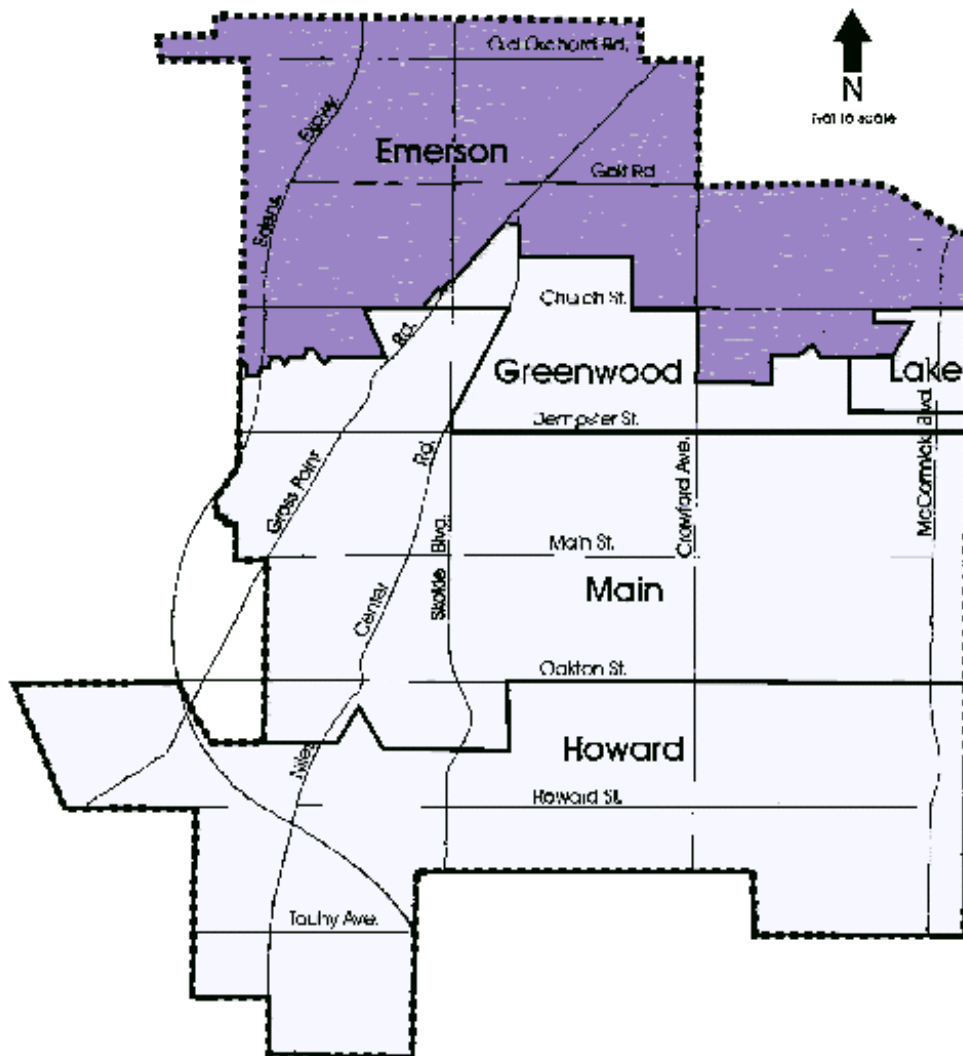
It is reasonable to expect that street storage would have a positive impact on the frequency and volume of CSOs and could be used to meet the Nine Minimum Controls established by EPA. The primary purpose of this study was to complete an analysis to evaluate the potential benefits of street storage with respect to reductions in the frequency and volume of CSOs. The analysis was completed using hydrologic and hydraulic computer modeling to represent the performance of the combined sewer system. XP-SWMM computer modeling software was utilized to conduct the analysis.

To efficiently perform the analysis, data previously developed for the Village of Skokie was utilized. The Village of Skokie has implemented a street storage program to provide 10-year protection from basement flooding. The street storage improvements were designed to function with TARP (the Tunnel and Reservoir Plan), deep tunnels constructed to provide an overflow for flows in excess of the interceptor system capacity. During dry weather, flows go from the Village's system to the MWRDGC's interceptor system. During wet weather, flows fill the interceptor sewer system, and then overflow into TARP. CSOs occur to the North Shore Channel when the capacity of the connections between the local systems and TARP is exceeded or when TARP is full.

Street storage combined with a deep tunnel solution to sewer capacity problems is effective in reducing CSOs to waterways, but is not an option in most communities. Therefore, the impacts the use of street storage independent of a TARP system need to be evaluated. This study utilized the data developed for Skokie modified to exclude TARP and replace it with discharge to a WWTP with CSOs to the adjacent waterway. This provided information about a combined sewer system discharging directly to a WWTP, as is the case for most existing combined sewer systems.

Two scenarios were evaluated in the study. The first scenario consisted of "pre-project" conditions, or the combined sewer system without implementation of street or subsurface storage. The second scenario represented conditions with street storage and subsurface storage that has been implemented in a basin in Skokie with characteristics representative of other combined sewer areas. The analysis incorporated flows for dry and wet weather conditions with and without street storage and was completed using the Emerson Street Sewer District (ESSD) basin of the Village (see Figure F-1). A 45-year rainfall record was used as the basis for evaluating potential CSO reductions attainable with street storage. The occurrence of CSOs was defined using "typical" wastewater treatment plant capacity. The number and volumes of combined sewer overflows was determined for scenarios with and without the street storage.

**Figure F-1**  
**Sewer Districts in Skokie**



## **Study Area Description**

The Village of Skokie is located adjacent to and directly north of the City of Chicago. The 5,510 acre area of the Village is divided into three sewer districts: the 1,255 acre Howard Street Sewer District (HSSD) in the southern part of the Village; the 2,300 acre Main Street Sewer District (MSSD) in the central part of the Village; and the 1,955 acre Emerson and Lake Street Sewer District (ELSSD) in the northern part. As discussed above, the 840 acre Emerson District was included in this analysis.

Precipitation occurs as rain, sleet, hail, and snow and ranges from showers of trace quantities to brief intense storms to longer duration rainfall or snowfall events. Precipitation is distributed throughout the year with an average annual total of 33.3 inches. Circular 172 prepared by the Illinois State Water Survey (1989) estimates that for a one hour storm, the 1, 10, and 100 year recurrence interval rainfall amounts are 1.49, 1.94, and 2.08 inches, respectively. For a 24 hour storm, the 1, 10, and 100 year amounts are 2.21, 3.86 and 6.70 inches, respectively.

Soils in the area are primarily from glacial deposits of the Pleistocene series. These glacial deposits have an approximate depth 60 feet and consist of many types of materials. About 25 percent of the study area are sandy soils, while the remainder has clay soils. Ground water levels tend to remain 10 to 15 feet below ground level in sandy areas with the exception of isolated perched lenses of shallower ground water.

The land in the ESSD generally slopes eastward toward the North Shore Channel. Slopes vary from 0.1 to 1 percent and the overall slope in many areas of the Village is a flat 0.2 percent. Surface runoff flows from the front lawn and driveway areas to the street. Flow in the street is along the curb line and gutters to the nearest inlet. Inlets are generally located midblock and at intersections. Due to the extremely flat conditions, few areas have a continuous drainage pattern from block to block. Trunk sewers in the combined system range in diameter from 30 inches to a maximum of 84 inches. Lateral sewers which are connected to trunk sewers range in diameter from 12 to 27 inches.

## **Study Approach**

### **Analysis Objectives**

The focus of this study was to quantitatively evaluate the potential benefits of street storage with respect to control of CSOs. The approach adopted for this study included components intended to consider “typical” combined sewer systems. The following study objectives were identified and incorporated into the impact analysis:

1. Evaluate the potential effects of street and underground storage for a typical

community that contains a combined sewer service area. Use one sewer district in the Village of Skokie as the basis for the analysis.

2. Assume that an overflow collection system such as TARP does not exist. The flows discharged from the combined sewer system will be directed to the wastewater treatment plant or overflow to a receiving stream.
3. Evaluate the effect of street storage on a community's ability to meet the Nine Minimum Controls, that have been developed by USEPA for control of CSOs.
4. Evaluate the effect of street storage on the frequency and volume of combined sewer overflows.
5. Evaluate the effect of street storage on the community's wastewater treatment facilities.

### **Analysis Methodology**

As previously discussed, detailed models were developed using SWMM to represent the performance of the combined sewer system in the ESSD. Models were developed to simulate performance of the system before and after the runoff control program was implemented. SWMM is an excellent tool for conducting sewer system analysis, however there are limitations to using the EXTRAN module of SWMM for continuous simulation.

To overcome the limitations of the EXTRAN module while utilizing historical precipitation, a two part approach was adopted for this analysis. The first part of the analysis consisted of completing simulations using the SWMM models developed for scenarios with and without street storage. Simulations were conducted to define the minimum rainfall event threshold causing combined sewer overflow. Simulations were completed for both scenarios using rainfall events selected to represent the range of events contained in the historical series. The results of the simulations were used in the second part of the analysis, which consisted of deriving CSO statistics from the entire record of rainfall events. CSO occurrences, volumes and peak flows were derived based on regression techniques applied to the simulation results of the strategically selected rainfall events.

An outline of the procedure used for the impact study is summarized below:

1. Develop SWMM models for the ESSD basin to represent scenarios with and without street storage.
2. Incorporate dry weather flows quantified from previously conducted flow monitoring programs.

3. Incorporate wet weather flows with runoff control facilities.
4. Verify model performance for the 10-year, 6-hour design rainfall event. Adjust parameters as necessary to correctly represent expected system discharge and storage volumes for the design event.
5. Develop model parameters to represent the scenario without runoff control facilities.
6. Verify model performance for the 10-year, 6-hour design rainfall event using earlier study results that quantified approximate surcharging depths.
7. Use the RAIN module of SWMM to convert the 45-year historical continuous precipitation record from the NOAA station at O'Hare International Airport to defined rainfall events.
8. Complete model simulations to determine which rainfall events will result in CSOs for wet weather flows with and without runoff control facilities.
9. Select rainfall events for simulation that are representative of the historical precipitation record. Complete model simulations for both scenarios using the selected rainfall events. Tabulate model results to determine CSO peak flow and CSO volume for each simulated rainfall event simulated.
10. Determine relationship for each scenario between CSO peak flows and CSO volumes with corresponding rainfall event characteristics. Use defined relationship to estimate CSO peak flow and CSO volume for all rainfall events in the 45-year historical series (See no. 7 above).
11. Develop statistics to describe the occurrence of CSO peak flows and CSO volumes to quantify the effects of street storage on CSOs.

### **Hydrologic and Hydraulic Computer Modeling**

Hydrologic and hydraulic modeling supporting the runoff control program dates back to the late 1980's. The original analysis of the ESSD was completed in 1987 using the System Analysis Model (SAM) computer modeling software, which was originally developed by CH<sub>2</sub>MHill. The analysis was limited to the major interceptors in the ESSD. The SAM model was run on a VAX computer system. In 1992, the sewer system model was converted into the HYDRA model, developed by Pizer, Inc.

XP-SWMM modeling software was used for this analysis. SWMM was selected because it offers advantages in evaluating CSOs when compared to the capability of models that were previously used for the ESSD. The hydraulic analysis capability of the EXTRAN module of SWMM is superior to the other models. For example, SWMM

explicitly solves the St. Venant equations for each model element at each time step during the model simulation. The ability to explicitly represent system surcharging, storage and volume are essential components to evaluating CSOs for a wide range of rainfall events.

### **Model Parameters**

Pipe and manhole data (pipe diameters, inverts and lengths, and manhole rim elevations) were taken from the existing HYDRA model and input into the EXTRAN module of SWMM. The dry weather flows, consisting of sanitary sewage and infiltration were input as constant point flows into the EXTRAN module of SWMM. The wet weather flows from foundation drains (0.007cfs/acre) and existing on-site detention facilities (41 cfs) were input into the model as a constant flow in the EXTRAN module. A flow rate of 2.0 cfs/acre was applied to the identified 26 acres of internal roof drains using the acreage and the rainfall hyetograph in the RUNOFF module of SWMM. Surface stormwater runoff was represented using the RUNOFF module. The ESSD was divided into 73 subbasins, which were tributary to manholes in the model. The area and percent impervious values were taken from previously completed analysis. The subbasin widths were derived from measurements of each basin and a general slope of 0.2 percent was used. The regulated catch basin flows were represented in the EXTRAN module at each manhole by defining orifice links to control release rates from each storage junction during the analysis. The non-regulated catch basin flows were developed in the RUNOFF module and directed to the appropriate modeled manholes in EXTRAN. The storage volume in each basin were determined and input into the EXTRAN module using the stepwise linear area method.

### **Dry Weather Flow**

Dry weather flows were considered to be sanitary sewage and infiltration. Sanitary sewage is flow from residential, commercial or industrial buildings. The base average daily residential flow was estimated based on the land use and the population served. A per acre contribution was developed for each type of residential land, single family, multi-family (2 to 4) and apartments. Residential flows varied from 0.006 to 0.02 cfs/acre.

The non-residential sanitary flows were divided into industrial and commercial flows. Commercial flows are those flows from offices, gyms, laundries, schools, and other commercial buildings. Sanitary flows from commercial buildings were estimated using the size of the property. Industrial flows are those flows from manufacturing facilities, warehouses, and other industrial buildings. Sanitary flows from industrial buildings were also estimated using the size of the property. Commercial and industrial flows varied from 0.04 - 0.02 cfs/acre.

Infiltration is primarily groundwater which enters the system through defective pipe and manholes or other openings. Infiltration tends to be a steady-state flow as far as

system modeling is concerned. The dry weather flows were all input as constant flows because these flows are very small as compared to the wet weather flows.

### **Wet Weather Flows**

Wet weather flows were considered to be foundation drains, roof drains, on-site detention release rates and surface stormwater runoff. The first three components were determined using flow monitoring and existing data. As part of the flow monitoring program, foundation drains from individual homes in ESSD were monitored. This data was determined to be similar to previous foundation flow monitoring data from the Howard Street and Main Street Sewer Districts. The foundation flow was estimated to be 0.007 cfs/acre and was input into the model as a constant flow.

The second wet weather flow component are roof drains. The Village required all single-family residences to disconnect their downspouts. Buildings without downspouts were assumed to have internal roof drains. It was decided to allow internal roof drains to be connected directly to the combined sewer because of the cost to disconnect them. A maximum peak flow rate of 2.0 cfs/acre was applied to the identified 26 acres of internal roof drains. To maintain the rainfall dependent characteristics of flow from roof drains, the roof area was represented as impervious tributary area in the model.

The third wet weather flow is the flow from existing on-site detention facilities. These flows were represented by the design outflow rate as provided by the Village. Eighty one (81) acres of existing on-site detention facilities were identified with a total release rate of 41 cfs which was input into the model as constant point flows.

### **Stormwater Runoff**

The first three wet weather flow inputs described above are considered to be fixed flows, that is these flows can not be regulated or changed. The fourth and final wet weather flow input is surface stormwater runoff. While the other types of wet weather flows cannot be regulated, the street storage and subsurface storage system was designed to control stormwater runoff component of wet weather flow.

Stormwater runoff was divided into two components, regulated catch basin flows and non-regulated catch basin flows. Regulated catch basin flows require storage of the surplus water not immediately allowed into the sewer within the project area. The regulated catch basin flows and associated storage volumes were determined as part of the runoff control program for the ESSD of Skokie. Non-regulated catch basin areas allow the runoff from rainfall events up to the 10-year design rainfall event to enter the sewer system without any restrictions. These non-regulated flows were only allowed on arterial streets.

### **Regulated Catch Basin Flows**

The first step of the analysis was to determine the capacity of the sewer system

available for carrying stormwater runoff. The total hydraulic capacity of the sewer system depends on the quantity of dry and wet weather flows and the level to which a sewer can surcharge without causing basement flooding or other damage. This capacity is also affected by the back water effect from limited capacity of downstream sewers. The maximum allowable rates at which runoff can be released into the sewer system were determined for all areas of the ESSD. These runoff rates ranged from 0.08 to 1.0 cfs per acre. Using the regulated runoff rate (cfs/acre) and the tributary area, a maximum allowable regulated flow from each catch basin was determined. Results of this analysis formed the basis for the design of the runoff control system and for determining the sewer capacity available for those areas which could not be regulated.

The second step was to determine the location and extent of intentional street ponding which can be achieved through flow regulators and minor street grade modifications (berms). Higher flows were allowed on streets with little storage available. Conversely, on streets which could pond large stormwater volumes, the flows were regulated to use the available storage capacity. The sewer capacity and the storage analyses were conducted concurrently with each analysis providing input to the other. The product of this analysis included delineation of street ponding elevations in allowable areas and identification of the volume of additional runoff which must be detained in other storage locations.

The third step was to site and size the additional storage facilities necessary to store flows in excess of street ponding capacity and where street ponding was not feasible to store runoff in excess of the regulated runoff rate. The locations and volumes of detention facilities needed to store the remaining volume from step two were determined. This step insured that the runoff control system for the ESSD would reduce sewer surcharging to prevent sewer backup into the basement during the 10-year recurrence interval storm.

#### **Non-regulated Catch Basin Flows**

The final component of the wet weather flows is the flow from non-regulated catch basins. These catch basins are located on arterial streets and allow the runoff from a 10-year recurrence interval storm to enter the combined sewer system. The Village designated the streets within the ESSD that were to be non-regulated streets. Currently, the Village has reconsidered this assumption and is installing regulators to restrict the runoff into the sewer system to that of a 10-year storm.

#### **Wastewater Treatment Plant Description**

The Village of Skokie does not own or operate a wastewater treatment plant (WWTP). Conveyance and treatment facilities are provided by the MWRDGC. Dry weather flows from the ESSD discharge to the MWRDGC interceptor located under McCormick Boulevard. Wet weather flows discharge first to the interceptor sewer system, then to

the TARP and if TARP is full, then to the North Shore Channel. To determine the impact of street storage on the number and volumes of CSOs, a theoretical WWTP was included in the analysis. Earth Tech recently completed a facility plan for the WWTP in Gary, Indiana. Since Gary has a large combined sewer service area, it was used as a basis for the theoretical WWTP for the ESSD. Theoretical ESSD flows were developed by prorating average and peak flows from the Gary WWTP. The Gary WWTP treats an average of 35.6 cfs on a dry day with a peak WWTP flow of 186 cfs. Flows larger than 186 cfs are bypassed into either the Little Calumet River or the Calumet River. The average dry weather flow from the ESSD is 12 cfs. Using the same ratio of average dry weather flow to peak capacity, the peak wet weather flow through the ESSD WWTP would be 65 cfs. A review of the Skokie flows showed that the flows from on-site detention facilities add up to 41 cfs. Therefore, the constant flows equal 53 cfs (12 cfs dry weather and 41 cfs on-site detention facilities). The roof and foundation drains and regulated catch basins also add additional flow. It was determined that 65 cfs was too small to use for this analysis. Because many communities with large peaking factors, both separate and combined systems, ie, Racine, WI, Kenosha, WI, Milwaukee, WI and the Greater Metropolitan Water Reclamation District of Greater Chicago, IL provide either storage or a flow through clarifier (typically with disinfection) for a portion of the flows that exceed the WWTP capacity. Therefore, it was decided to provide a flow through clarifier to allow the ESSD facility to handle a peak wet weather flow of 100 cfs. Therefore, the ESSD treatment facility assumed for this analysis accepts up to 100 cfs prior to the occurrence of a combined sewer overflow.

## **Model Verification**

### **Flow Monitoring Program**

In 1986, a flow monitoring program was conducted in the ESSD. A total of \_\_\_ flow meters, \_\_\_rain gauges, and two foundation monitors were installed for \_\_\_ months. This flow monitoring program provided dry weather and wet weather flow data at strategic points in the districts. In addition to sewer flows, a foundation drain monitoring program was also done. This data was used to develop dry weather flows and verify wet weather flows used in the hydraulic models. The parameter development completed during previous analysis and observed system performance was used as the basis for completing the SWMM models used in this analysis.

### **Design Storm Simulation**

In addition to the flow monitoring data described above, simulation of the system design rainfall event was used for model verification. The 10-year, 6-hour recurrence interval rainfall event was the design storm for the design of the ESSD runoff control system. Therefore, the 10-year, 6-hour rainfall event was simulated. The simulated storage volumes and flows (sanitary, foundation drains, roof drains, existing on-site detention facilities, and regulated catch basin flows) were compared and confirmed with expected

results for the 10-year design storm. The regulated flows were confirmed by comparing design parameters with simulation results for storage volumes and peak flows at regulated manholes. The non-regulated catch basin flows were verified when the simulated peak flow at the outfall matched the design peak flow of 300 cfs. At this point the model was considered to be verified for use in performing additional analysis.

### ***Combined Sewer Overflow Simulation***

As previously discussed, detailed SWMM models were developed to represent the performance of the combined sewer system in the Emerson Street study area. Models were developed to simulate performance of the system before and after the runoff control program was implemented. SWMM is an excellent tool for conducting sewer system analysis, however there are limitations to using the EXTRAN Block of SWMM for continuous simulation. Therefore, a two part approach was adopted for this analysis to utilize the rigorous hydraulic analysis capability of the SWMM EXTRAN Block and still obtain results for a long term period of recorded precipitation data. The first part of the analysis consisted of completing simulations using the SWMM models developed for both the pre-project scenario and the street storage scenario. Simulations were conducted to define the minimum rainfall event threshold causing combined sewer overflow. Simulations were then completed for both scenarios for approximately 25 rainfall events. The results of the simulations were used in the second part of the analysis, which consisted of deriving CSO statistics from the entire record of rainfall events. CSO occurrences, volumes and peak flows were derived based on the regression techniques applied to the simulation results of the strategically selected the rainfall events.

### **Historic Precipitation Record**

Historic precipitation data from the NOAA station at Chicago O'Hare International Airport (ORD) was obtained for the period WY1949 to WY1993. Initially, the precipitation record was processed using the RAIN Block of SWMM. The RAIN Block was used to read the continuous rainfall record and define individual rainfall events. For the purpose of this study, a rainfall event was characterized as durations of measured precipitation surrounded by 12-hour intervals during which precipitation was not measured. The 12-hour interval was an arbitrary choice and deemed to be a sufficient recovery time for the Emerson Street system. The continuous record was processed by the RAIN block to gain information such as rainfall depth, maximum rainfall intensity and average rainfall intensity to describe each rainfall event. This information was used to correlate CSO occurrences with defined rainfall events. Table F-1 presents a summary of the defined rainfall events according to rainfall depth and maximum rainfall intensity.

The graphs depicted in Figure F-2, F-3 and F-4 were developed using the rainfall events extracted from the historical precipitation record using the RAIN Block of SWMM. The graphs include plots of rainfall depth, maximum rainfall intensity and

average rainfall intensity for the rainfall events defined in the historical record. As one would expect, the graphs show significant scatter among the simple descriptors such as rainfall depth and rainfall intensity. However, the graphs do indicate trends, upper and lower limits and frequency characteristics that describe the historical rainfall events.

Use of rainfall events from a long term precipitation record was advantageous for a number of reasons. For example, realistic rainfall patterns and system response is represented with the use of recorded rainfall events instead of synthetic design rainfall distributions. The frequent occurrence of CSOs also is better addressed by using a historical precipitation record to derive frequency and performance statistics than by using design rainfall events. Verification of the performance of a street storage system with a variety of rainfall depths, durations and intensities was also an advantage gained from using recorded rainfall.

### **Correlation of Combined Sewer Overflows and Rainfall**

Rainfall events from the record were strategically selected to characterize CSO occurrence for the study area while minimizing the number of simulations required. Initially, simulations were conducted to define the minimum rainfall event threshold causing combined sewer overflow. Simulations were then completed for both scenarios for approximately 25 rainfall events. The simulated events were selected to be representative of the variety in rainfall depth, maximum intensity and average intensity present in the historical precipitation record. Particular emphasis was placed on simulating rainfall events near the threshold at which overflows occur. This approach was adopted to define performance for the most frequent rainfall events, which were also believed to dominate the annual CSO statistics. The results of the simulations were used as the basis for deriving CSO statistics from the entire record of rainfall events. Table F-2 includes summary information for the simulated rainfall events and Table F-3 presents simulation results for each rainfall event.

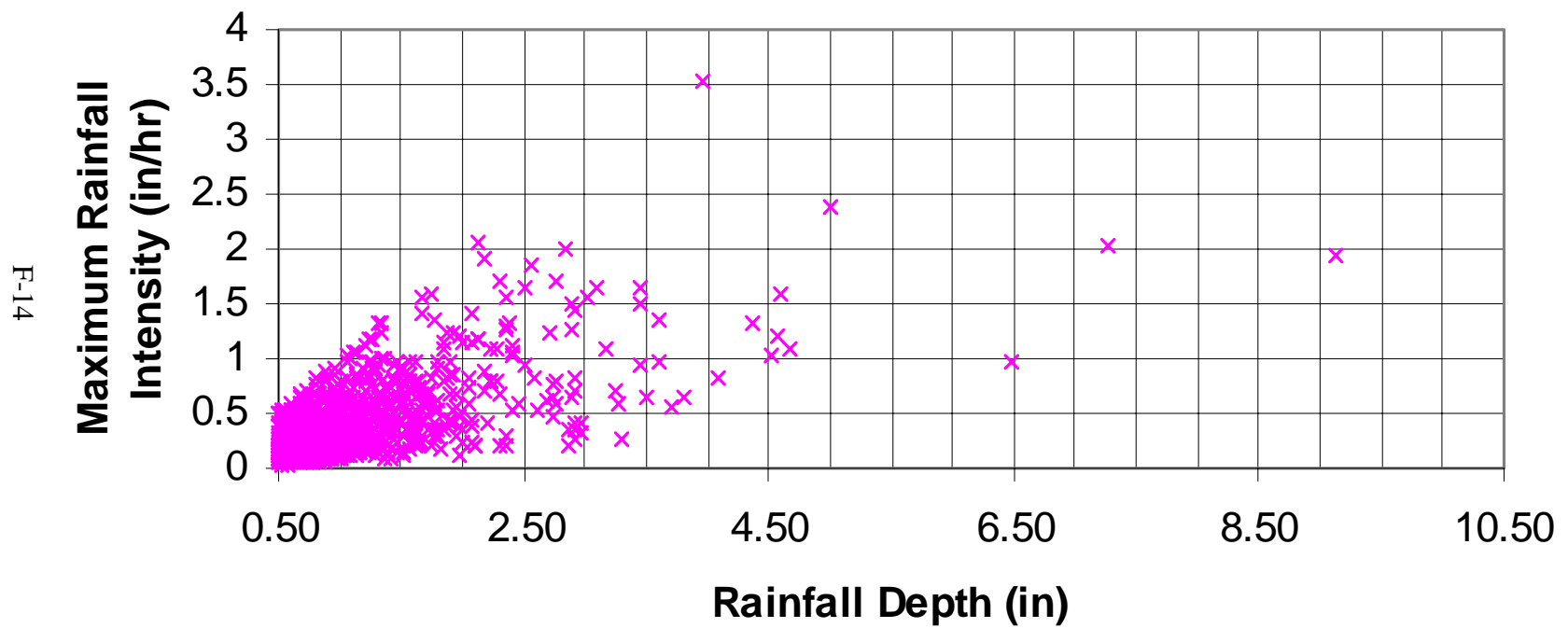
**Table F-1**

### **Rainfall Event Summary**

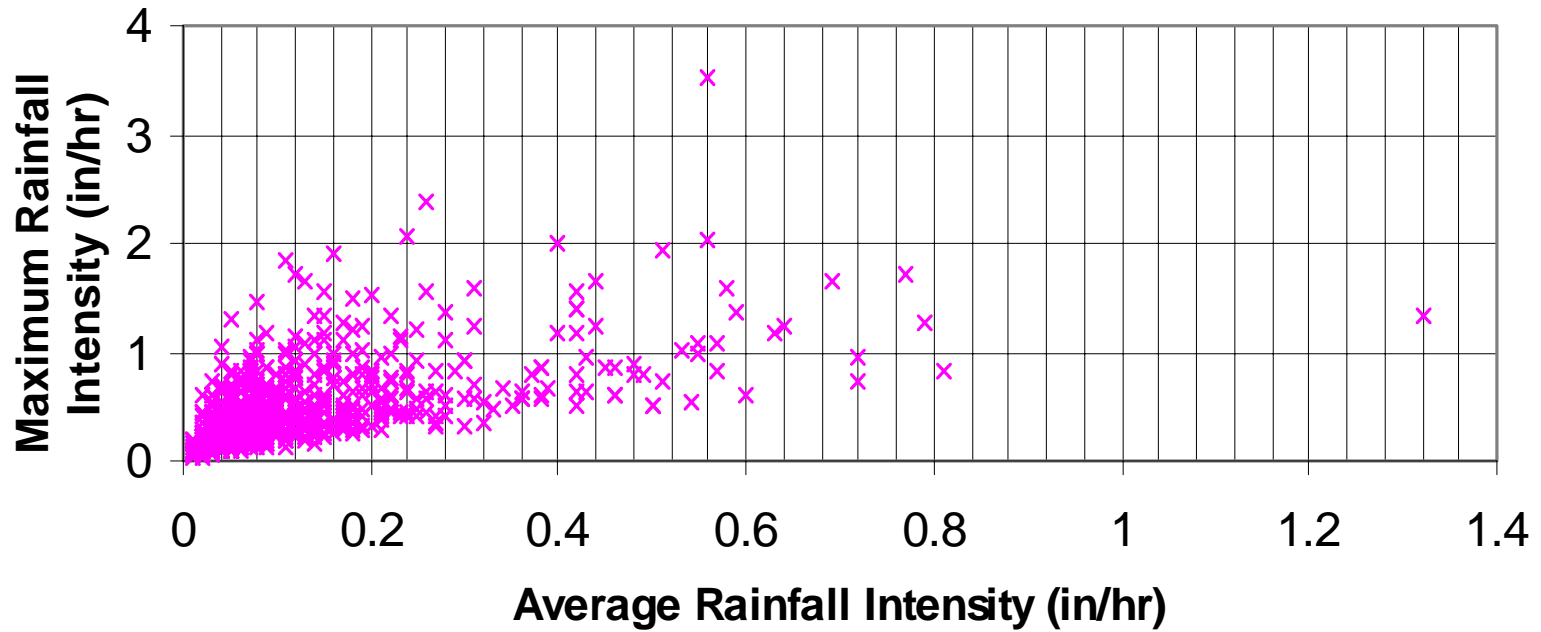
<b>Rainfall Depth (inches)</b>	<b>Number of Occurrences</b>	<b>Cumulative Subtotals</b>	<b>Maximum Rainfall Intensity (inches/hour)</b>	<b>Number of Occurrences</b>	<b>Cumulative Subtotals</b>
10.00	--	--	10.00	--	--
9.00	1	1	9.00	0	0

8.00	0	1	8.00	0	0
7.00	0	1	7.00	0	0
6.00	0	1	6.00	0	0
5.00	0	1	5.00	0	0
4.00	5	6	4.00	0	0
3.00	15	21	3.00	1	1
2.50	27	48	2.50	0	1
2.00	37	85	2.00	2	3
1.50	96	181	1.50	13	15
1.00	241	422	1.00	37	52
0.50	575	997	0.50	205	257
0.20	888	1885	0.20	657	914
0.10	624	2509	0.10	687	1601
0.05	490	2999	0.05	689	2290
0.02	532	3531	0.02	761	3051
0.01	280	3811	0.01	413	3464
0.00	456	4267	0.00	805	4267

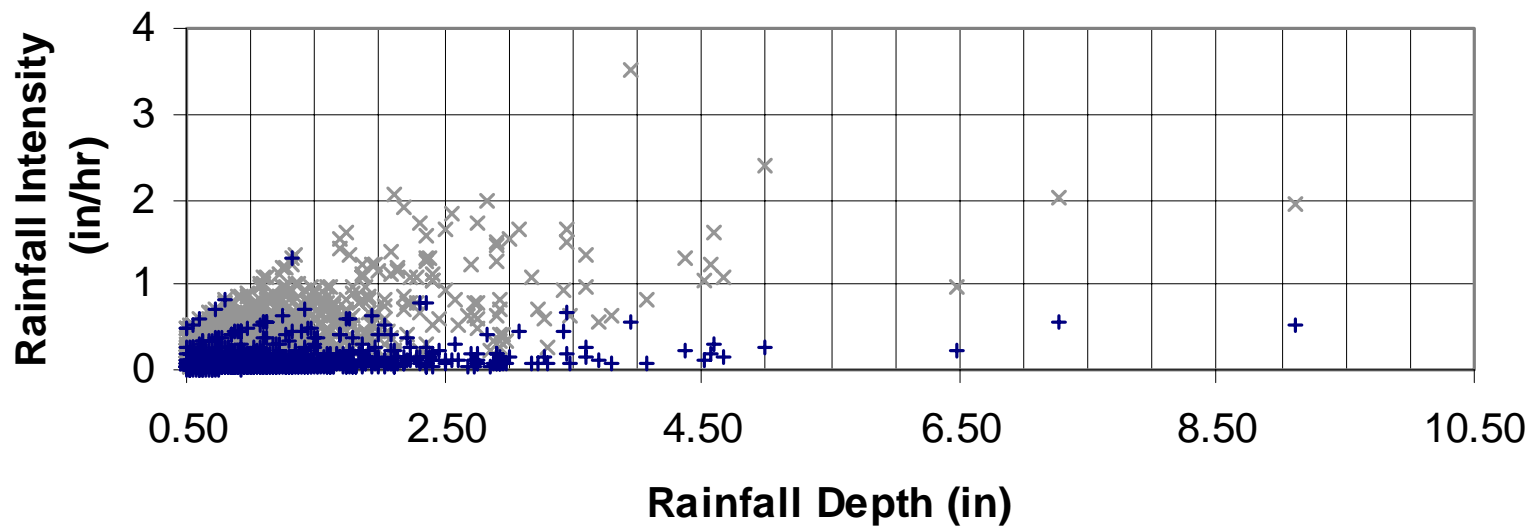
**Figure F-2**  
**Rainfall Depth vs. Maximum Rainfall Intensity**



**Figure F-3**  
**Maximum Rainfall Intensity vs.**  
**Average Rainfall Intensity**



**Figure F-4**  
**Rainfall Depth vs. Rainfall Intensity**



× Maximum Intensity (in/hr) + Average Intensity (in/hr)

**Table F-2**  
**Simulated Rainfall Events**

<b>Event Start Date</b>	<b>Event Duration (hours)</b>	<b>Event Volume (inches)</b>	<b>Maximum Intensity (inches/hour)</b>	<b>Average Intensity (inches/hour)</b>
3/19/48	19	5.00	2.39	0.26
10/9/69	33	4.68	1.10	0.14
4/24/54	8	3.70	0.57	0.10
8/17/90	10	3.01	1.55	0.15
11/26/90	10	2.98	0.33	0.08
8/31/89	18	2.56	1.85	0.11
8/29/55	16	2.46	0.60	0.22
6/13/50	4	1.99	1.16	0.40
9/24/61	22	1.98	0.46	0.11
11/4/88	7	1.50	0.92	0.30
4/12/83	18	1.49	0.42	0.03
9/15/92	15	1.25	1.19	0.63
6/4/53	23	1.25	0.52	0.06
9/25/93	11	1.25	0.29	0.07
8/17/83	1	1.00	0.74	0.17
11/13/51	5	1.00	0.32	0.07
9/12/77	11	1.00	0.15	0.04
9/17/49	23	0.75	0.42	0.11
3/28/51	5	0.75	0.17	0.01
12/16/87	20	0.75	0.07	0.02
6/20/68	4	0.60	0.60	0.60
9/23/63	18	0.60	0.30	0.10
7/18/57	12	0.60	0.09	0.02
5/27/56	16	0.55	0.51	0.14
7/1/83	3	0.55	0.33	0.06
12/7/78	3	0.55	0.13	0.03

**Table F-3**  
**Overflow Simulation Results**

Event Start Date	Pre-project Scenario		Street Storage Scenario		
	Peak Overflow (cfs)	Overflow Volume (acre-feet)	Peak Overflow (cfs)	Overflow Volume (acre-feet)	Overflow Volume Reduction (%)
3/19/48	464.5	115.2	278.3	111.3	3.36
10/9/69	353.1	110.6	229.7	101.3	8.45
4/24/54	116.2	39.0	86.3	35.6	8.72
8/17/90	427.7	67.4	233.7	60.3	10.64
11/26/90	61.8	19.3	55.3	16.9	12.61
8/31/89	418.9	50.1	223.7	44.8	10.60
8/29/55	114.0	31.6	82.7	27.9	11.86
6/13/50	225.7	30.9	150.2	27.2	12.03
9/24/61	66.8	8.8	16.9	0.1	99.06
11/4/88	177.8	19.7	113.3	16.7	15.48
4/12/83	67.1	7.7	--	--	100.00
9/15/92	199.5	15.7	119.0	12.8	18.58
6/4/53	51.2	5.6	26.0	3.0	45.73
9/25/93	45.1	5.6	33.9	4.2	25.35
8/17/83	141.6	14.4	95.9	11.1	22.65
11/13/51	34.8	4.2	25.9	2.8	33.15
9/12/77	--	--	--	--	--
9/17/49	37.1	3.6	22.1	2.0	44.30
3/28/51	--	--	--	--	--
12/16/87	--	--	--	--	--
6/20/68	73.1	5.2	42.3	3.2	38.32
9/23/63	21.7	1.7	11.4	0.6	66.13
7/18/57	--	--	--	--	--
5/27/56	35.8	1.6	9.1	0.3	83.04
7/1/83	--	--	--	--	--
12/7/78	--	--	--	--	--

The simulation results presented in Table F-3 formed the basis for determining CSO occurrence and assigning CSO volumes to rainfall events contained in the historical record. The relationship between rainfall event characteristics and CSO occurrence, flow and volume was determined by regression of the simulated results. A third order polynomial was fitted to the simulated CSO volumes using rainfall depth, maximum intensity and average intensity. Figure F-5, F-6 and F-7 demonstrate the consistency between simulated CSO data and predicted CSO data based on the regression relationship.

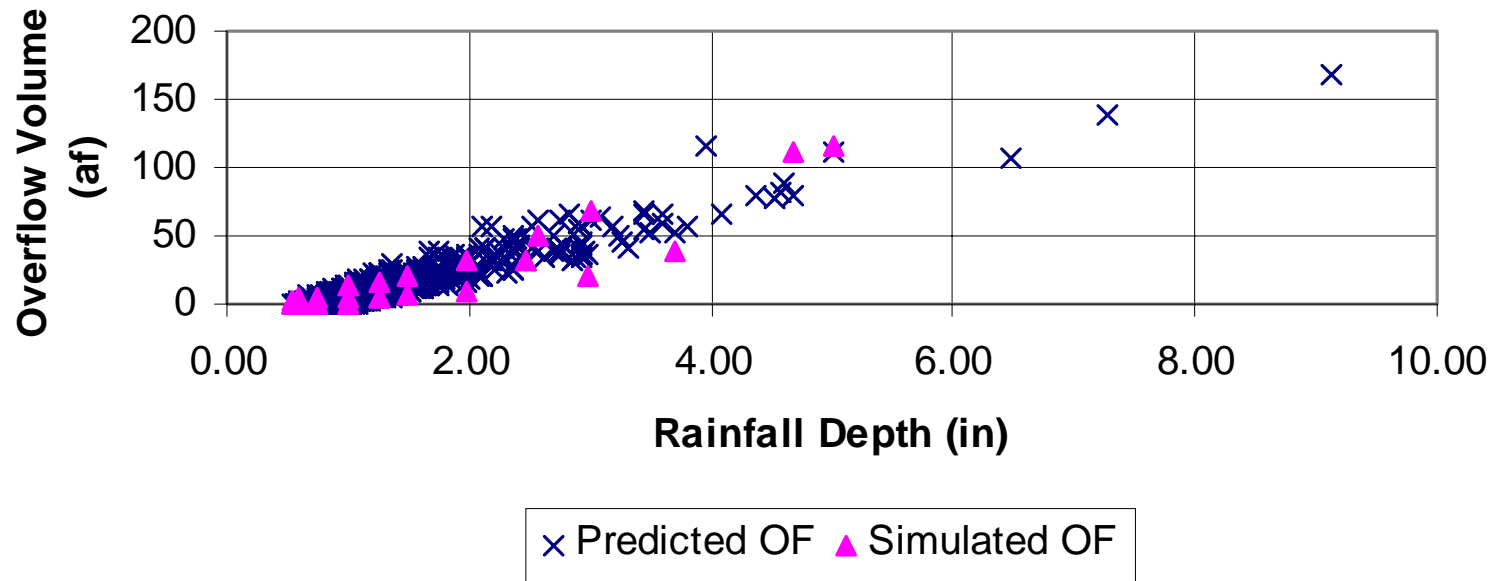
### ***Analysis Results***

Annual statistics were generated for WY1949 to WY1993. Table F-4 presents the computed statistics, which include annual number of CSO occurrences, annual CSO volume without street storage, annual CSO volume with street storage, annual percent reduction in CSO volume with street storage. In addition to the regression that was completed to assign CSO occurrence and volume to historic rainfall events, the data was further analyzed to investigate the relationships defining CSO peak flow and reductions in CSO volume and peak flow attainable with provision of street storage. Curve fitting techniques available in Microsoft EXCEL were used to quantify the apparent relationships between various data sets.

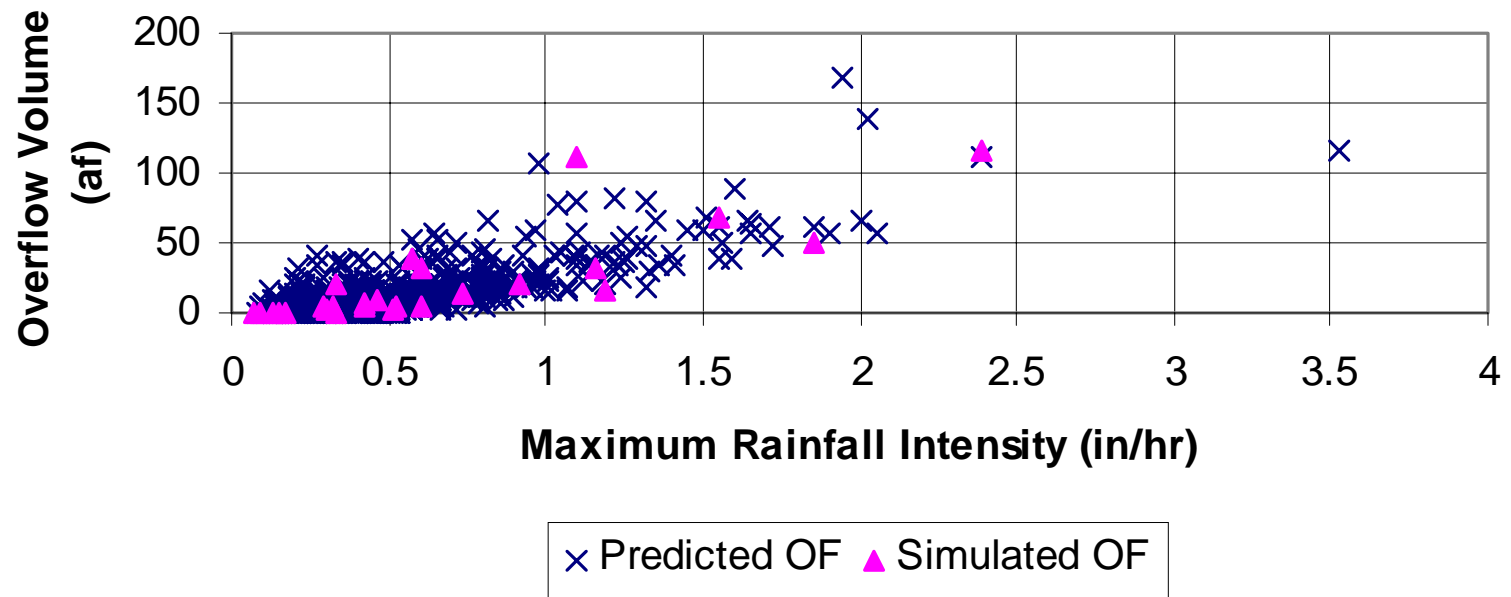
Figure F-8 presents pre-project overflow volume plotted against overflow volume reduction. The plot shows a well defined relationship between overflow volume reduction and pre-project overflow volume and is well represented by the fitted power function also shown in the figure. The data indicated significant reductions in overflow volumes, especially for events producing overflow volumes that were less than 20 acre-feet. As indicated in Figure F-8, street storage resulted in reductions of at least 20% for overflow volumes of approximately 20 acre-feet. The trend in percent reduction resulting with street storage increased dramatically as overflow volume decreases. The potential benefits from street storage become even more apparent considering that the average overflow volume for pre-project conditions was 15.9 acre-feet and the median overflow volume was 10.0 acre-feet. Applying the fitted curve in Figure F-8, street storage reduced overflow volumes for over half of the individual events by 30% or greater.

Graphs were also developed to examine possible relationships between provision of street storage and reductions in CSO peak flows. As shown in Figure F-9, there does not appear to be a well defined trend between CSO peak flow and rainfall depth. However, there does appear to be a trend in comparisons between CSO peak flow and maximum rainfall intensity. Figure F-10 presents the CSO peak flows resulting from the simulations compared with maximum rainfall intensity from each respective rainfall event incorporated in the simulation. Figure F-10 also contains second order polynomial curves fitted to the CSO peak flows for the pre-project scenario and the

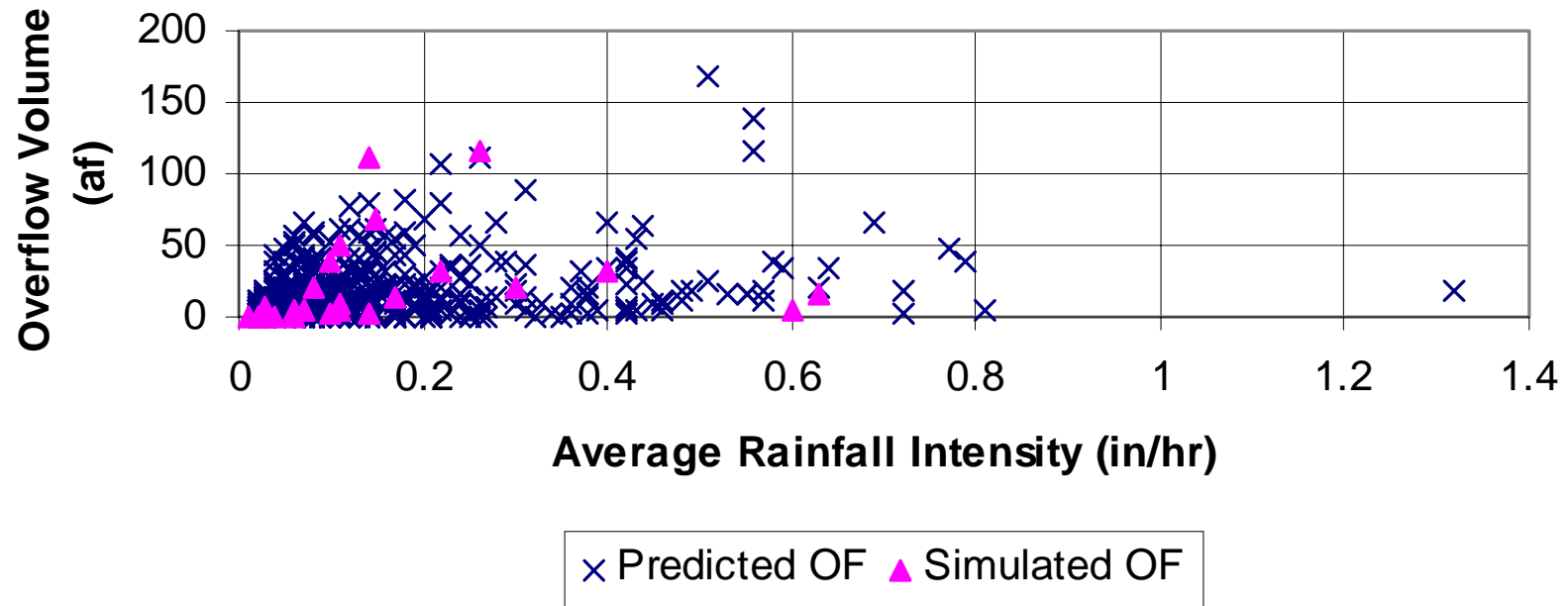
**Figure F-5**  
**Overflow Volume vs. Rainfall Depth**  
**Pre-project Scenario**



**Figure F-6**  
**Overflow Volume vs. Maximum Rainfall Intensity**  
**Pre-project Scenario**



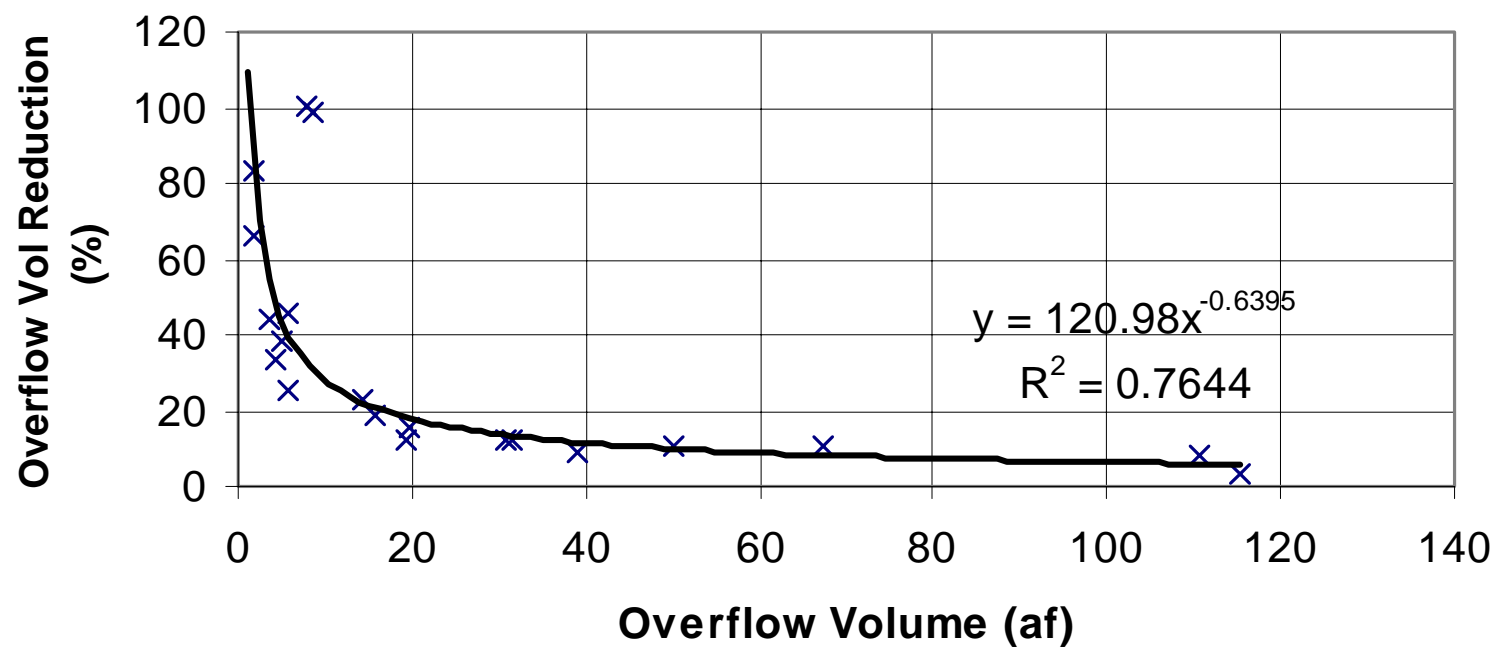
**Figure F-7**  
**Overflow Volume vs. Average Rainfall Intensity**  
**Pre-project Scenario**



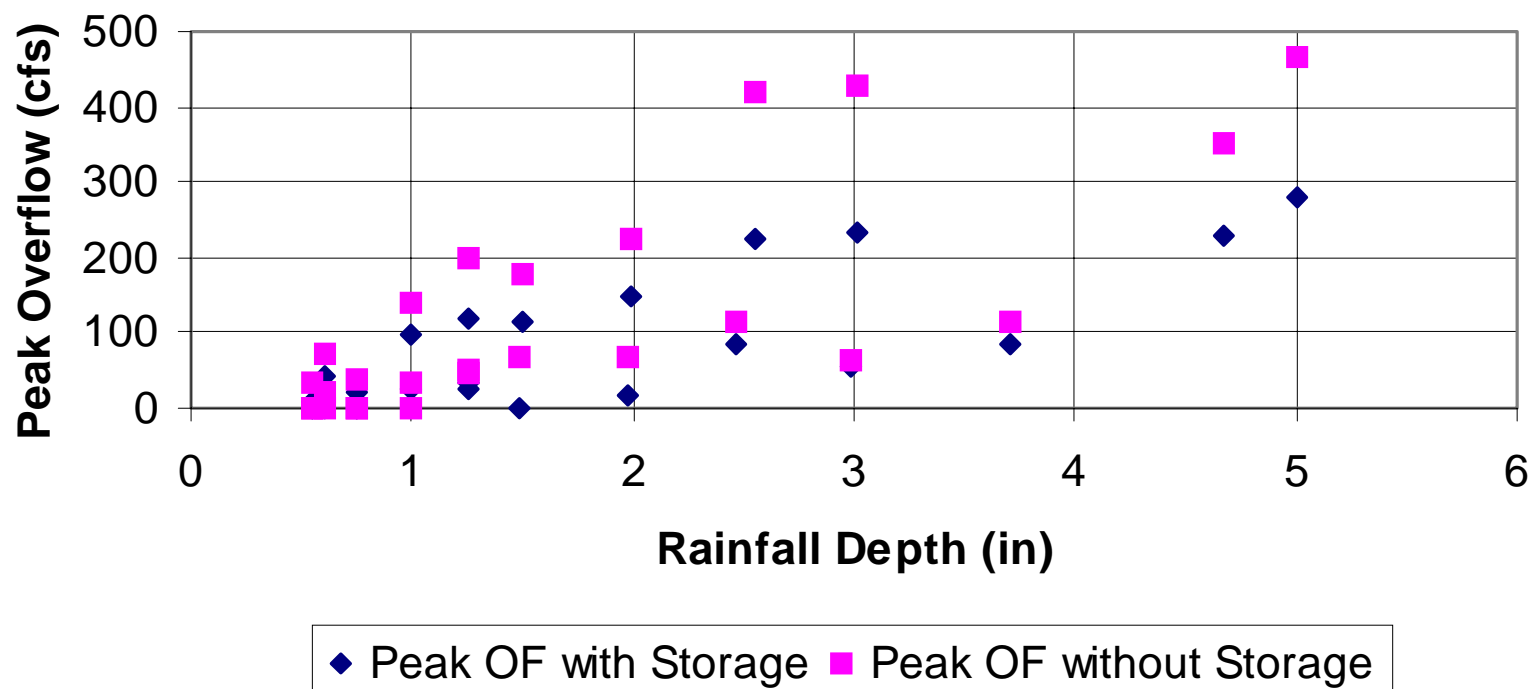
**Table F-4****Annual Overflow Statistics**

<b>Annual CSO Statistics</b>	<b>Pre-project Scenario</b>		<b>Street Storage Scenario</b>		
	<b>Number of CSOs</b>	<b>CSO Volume (acre-feet)</b>	<b>Number of CSOs</b>	<b>CSO Volume (acre-feet)</b>	<b>CSO Volume Reduction (%)</b>
Annual Average	12.62	197.98	11.24	162.44	19.23
Annual Median	12	187.91	10	147.54	18.79
Annual Maximum	23	478.42	22	415.68	29.48
Annual Minimum	6	86.92	5	63.77	9.24
Annual Standard Deviation	4.00	92.57	3.69	82.05	4.40

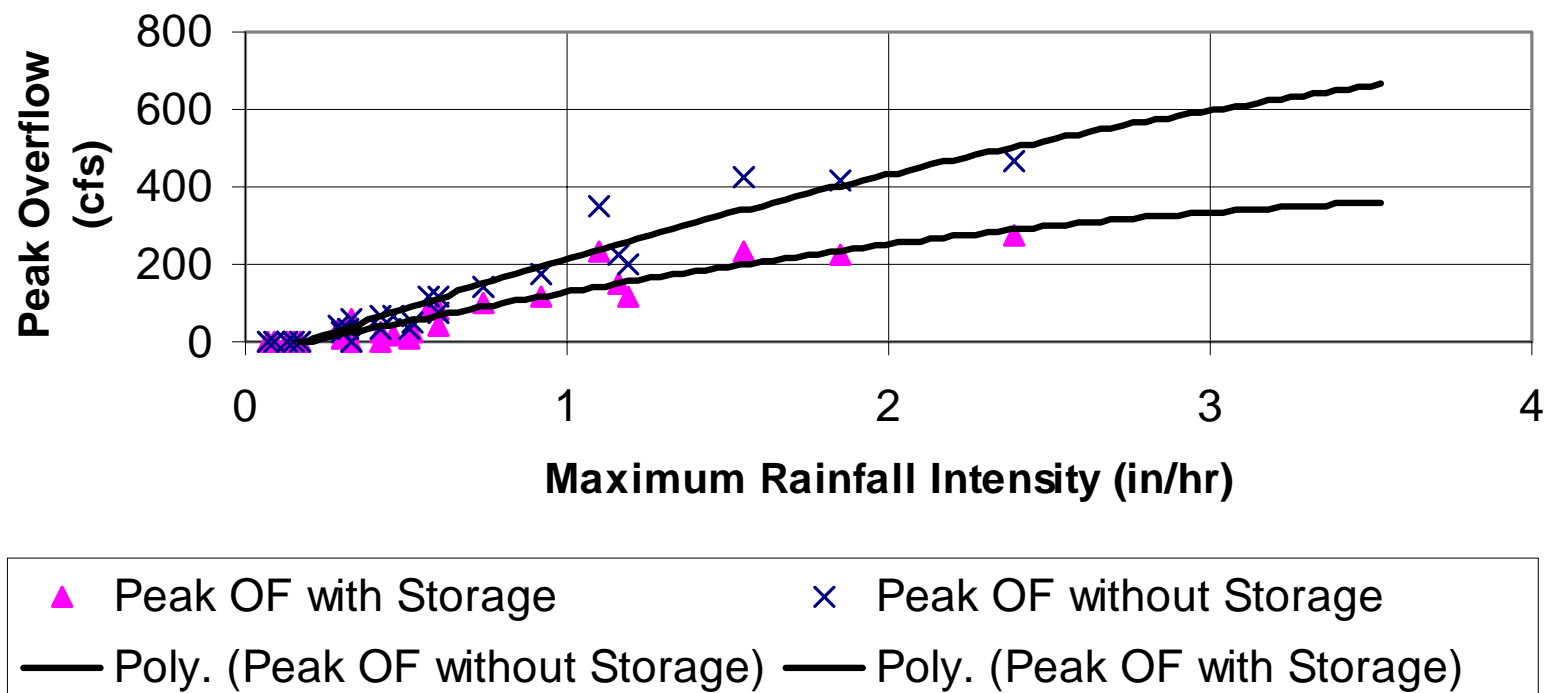
**Figure F-8**  
**Overflow Volume Reduction vs. Overflow Volume**



**Figure F-9**  
**Peak Overflow vs. Rainfall Depth**



**Figure F-10**  
**Peak Overflow vs. Maximum Rainfall Intensity**



street storage scenario.

## ***Conclusions***

The graphs and tables summarizing the CSO simulation and annual statistics clearly demonstrate that street storage does contribute to reducing both CSO volumes and peak flows. The data indicated that street storage resulted in a reduction of overflow volume of 30% or greater for approximately half of the overflow occurrences. This trend is consistent with objectives included in the Nine Minimum Controls such as treating the first flush and maximizing system storage.

Unfortunately, the results of this analysis did not indicate significant reduction in CSO occurrence and frequency. The study area selected for this case study was based on an area where street storage improvements have actually been constructed. This fact lends credibility to the improvement components and street storage volumes incorporated into the SWMM models developed for this study. It should be noted, however, that the improvements in the Emerson Street study area were conceptualized and developed to function with the MWRDGC TARP system. As a result, this system provides significantly greater capacity to accept system discharge than would normally be received by typical treatment plant capacities. The street storage system analyzed for this study was optimized to work in conjunction with improved sewer system capacity to provide protection to the residents for the 10-year design rainfall event. The street storage system was not specifically developed or optimized for the specific purpose of eliminating and reducing CSO impacts. It is probable that even greater benefits might have been realized had control of CSOs been an original objective during development of the street storage system.

Provision of street storage as a CSO control technology clearly offers benefits beyond simply controlling CSO impacts. Street storage can provide a cost-effective means for addressing capacity limitations in combined sewer systems that are not addressed by any current CSO control technologies. Based on the potential identified in this case study for street storage to contribute to reductions in both CSO volumes and peak flows, additional research and investigation is recommended to further explore and quantify the benefits of street storage with respect to CSO impacts. Additional research and investigation should be formulated to quantify the benefits of street storage to address CSO water quality, CSO impacts and compatibility with other CSO control technologies. The following are specific examples of additional research and investigation:

- Conduct monitoring of CSO effluent from areas with and without street storage to evaluate potential water quality benefits attainable with provision of street storage.
- Conduct analysis to determine the significance of different land use types on the potential water quality benefits attainable with provision of street

storage.

- Conduct analysis to evaluate the compatibility of street storage with other identified CSO control technologies. Evaluate potential design and cost reductions for CSO control technologies resulting from implementation with street storage.
- Evaluate design modifications required for street storage systems optimized for CSO control compared to street storage systems optimized to prevent basement and surface flooding.
- Conduct analysis to investigate the potential for implementing street storage in various regions of the United States. Identify possible regional limitations for implementing street storage for CSO control.
- Conduct a sensitivity analysis to evaluate the impact of the size of the WWTP along with the street storage on the amount of overflows. This will allow us to further evaluate the effect of street storage on the community's wastewater treatment facilities.

**Appendix G**

**Construction Costs  
for  
Skokie Street Storage System  
Adjusted to 1999**

SYSTEM COMPONENT	YEARS OF CONSTRUCTION	ORIGINAL CONSTRUCTION COST(1)	ENR INDEX FOR YEAR(S) OF CONSTRUCTION(2)	CONSTRUCTION COST ADJUSTED TO 1999(3)
		\$		\$
Roadway Berms	1984	42450	4146	61351
Roadway Berms	1985	1325415	4195	1893179
Tanks, Sewer	1985	1689577	4195	2413336
Relief Sewer	1986-87	4930781	4351	6790448
Roadway Berms	1988	1547510	4519	2051932
Surface Detention Facility	1989	835771	4615	1085144
Tanks, Sewer, Surface Detention Facility	1989	7834524	4615	10172149
Tanks, Sewer, Surface Detention Facility	1990	4992485	4732	6321845
Roadway Berms	1990	1170665	4732	1482381
Tanks, Sewer, Surface Detention Facility	1991-92	4712949	4910	5751526
Tanks, Sewer	1992	2998451	4985	3604156
Surface Detention Facility	1994	946480	5408	1048689
Tanks, Sewer	1993-94	3153684	5309	3559404
Tanks, Sewer, Surface Detention Facility	1994-95	4422855	5440	4871645
Tanks, Sewer	1995	1686775	5471	1847406
Tanks, Sewer	1995	766109	5471	839065

Tanks, Sewer Relief Sewer	1996-97	13100078	5723	13715825
Sewer	1997-98	6887763	5873	7027324
Tanks, Sewer Water Main	1998	185023	5920	187273
	1999	3508316	5992	3508316

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**TOTALS:**

**66737661**

<b>78232393</b>
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**Footnotes:**

- 1) Based on actual costs with the exception of 1999 which is the engineer's estimate.  
Source: Carr, 1999.
- 2) Engineering News Record (ENR) Construction Cost Indices were obtained from [www.enr.com](http://www.enr.com).  
The annual average value was used for one year construction periods.  
The average of annual averages was used for two year construction periods.
- 3) ENR index used for 1999 (February) is: 5992

**File Name: SkokieStreetStorageCosts**

## Glossary

Note: Definitions are quoted from USEPA (August, 1998) except for terms denoted with (\*) at the end of the definition. Definitions of these terms are developed in this report or taken from indicated sources.

***Berm:*** A low structure constructed across a street, from curb to curb, and intended to temporarily impound water on its upstream side. The crest or top of the berm when viewed along the longitudinal axis of the street, is horizontal. It is in effect, a spillway.  
(\*)

***Catch Basin:*** A chamber or well, usually at the street curblin, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump to retain grit and below detritus the point of overflow; whereas, a stormwater inlet does not have a sump and does not trap sediment.

***Combined Sewer:*** A sewer receiving intercepted surface (dry- and wet-weather) runoff, municipal (sanitary and industrial) sewage, and subsurface waters from infiltration.

***Combined Sewer Overflow (CSO):*** Discharge of a mixture of stormwater and domestic waste when the flow capacity of a sewer system is exceeded during rainstorms.

***Computer Model:*** A model in which the mathematical operations are carried out on a computer.

***Cost-Effective Solution:*** A solution to a problem that has been identified as being financially optional (e.g., the solution associated with the knee-of-the-curve of a cost-benefit relationship).

***Detention:*** The slowing, dampening, or attenuating of flows either entering the sewer system or within the sewer system by temporarily holding the water on a surface area, in a storage basin, or within the sewer itself.

***Flow Regulator:*** A passive, gravity device that regulates the flow of stormwater into a combined sewer. (\*)

**National Pollutant Discharge Elimination System (NPDES):** The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the Clean Water Act.

**Nonpoint Source:** Diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by stormwater. Common nonpoint sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

**Permit:** An authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

**Pollutant:** A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the environment. The term includes pathogens, toxic metals, carcinogens, oxygen-demanding materials, and all other harmful substances. With reference to nonpoint sources, the term is sometimes used to apply to contaminants released in low concentrations from many activities that collectively degrade water quality. As defined in the federal Clean Water Act, pollutant means dredged spoil; solid waste; incinerator residue; sewage; garbage; sewage sludge; munitions; chemical wastes; biological materials; radioactive materials; heat; wrecked or discarded equipment; rock; sand; cellar dirt; and industrial, municipal, and agricultural waste discharged into water.

**Pollution:** Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical and radiological integrity of water.

**Publicly Owned Treatment Works (POTW):** Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

**Receiving Waters:** Natural or man-made water systems into which materials are discharged.

**Sewer:** A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. “Sanitary” sewers carry household, industrial, and commercial waste. “Storm” sewers carry runoff from rain or snow. “Combined” sewers handle both.

**Source Control:** A method of abating storm-generated or CSO pollution at the upstream, upland source where the pollutants originate and/or accumulate.

**Storm Sewer:** A sewer that carries intercepted surface runoff, street wash and other wash waters, or drainage, but excludes domestic sewage and industrial wastes except for unauthorized cross-connections.

**Stormwater:** Stormwater runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not infiltrate into the ground or evaporate because of impervious land surfaces but instead flows onto adjacent land or watercourses or is routed into drain/sewer systems.

**Street Storage.** A system that mitigates surcharging of CSSs, SSSs and stormwater systems by temporarily storing stormwater in a controlled fashion on the surface (mainly on-street but some off-street) and, as needed, below streets. Stormwater is stored close to the source, that is, where it falls as precipitation, and prior to its entry into the sewer system. The full volume of stormwater runoff is accepted into the sewer system but peak rates are reduced, as a result of the storage, to flow that can be accommodated without surcharging. (\*)

**Surface Runoff:** Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.

**Surface Water:** All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.

**Watershed Protection Approach (WPA):** The U.S. EPA's comprehensive approach to managing water resource areas, such as river basins, watersheds, and aquifers. WPA has four major features: targeting priority problems, stakeholder involvement, integrated solutions, and measuring success.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

***Wet-Weather Flow:*** Usually referred to as the flow in a combined sewer system with stormwater, but may also constitute the flow in a separate storm or sanitary drainage system with stormwater.

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